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JOURNAL

OF THE

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ASSOCIATION OF ENGINEERING SOCIETIES.

Boston, St. Louis, Chicago, Cleveland, Minneapolis, St Paul.

TRANSACTIONS

Of the Boston Society of Civil Engineers, the Engineers' Club of St. Louis, the Western Society of Engineers, the Civil Engineers' Club of Cleveland, the Engineers' Club of Minnesota, and the Civil Engineers' Society of St. Paul.

VOLUME IV.

November, 1884, to October, 1885.

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VOLUME IV., NOV., 1884, TO OCT., 1885.

ASSOCIATION OF ENGINEERING SOCIETIES.

For the purpose of securing the benefits of closer union and the advancement of mutual interests, the Engineering Societies and Clubs hereunto subscribing have agreed to the following

ARTICLES OF ASSOCIATION.

ARTICLE I.

Name and Object.

The name of this Association shall be "The Association of Engineering Societies." Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies.

ARTICLE II.

Organization.

SEC. 1. The affairs of the Association shall be conducted by a Board of Managers, under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a Chairman and a Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

Duties of Officers.

SEC. 1. The Chairman, in addition to his ordinary duties shall countersign all bills and vouchers before payment, and present an annual report of the transactions of the Board ; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services, to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for counter-signature. He shall receive all fees and moneys paid to the Association, and hold the same under such rules as the Board shall prescribe.

ARTICLE. IV.

Publications.

SEC. 1. Each society shall decide for itself what papers and transactions of its own it desires to have published, and shall forward the same to the Secretary.

SEC. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a

mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publication such abstracts and translations from scientific and professional journals and society transactions as may be deemed of general interest and value.

ARTICLE V.

Conditions of Participation.

SEC. 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues, after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

Amendments.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating societies.

ARTICLE VII.

Time of Going into Effect.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

BOSTON SOCIETY OF CIVIL ENGINEERS

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. IV. November, 1884. No. 1.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE CREEPING OF RAILS ON THE ST. LOUIS BRIDGE.

BY J. B. JOHNSON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read October 22, 1884.]

There is an interesting phenomenon connected with the operating of the St. Louis Bridge, a satisfactory explanation of which has never come to the writer's notice, and a safe means of preventing which has not yet been found. The object of this paper is to describe the action, to offer an explanation of the cause, and to suggest a remedy.

The phenomenon consists in a movement of the rails, forming the track, of about *a foot a day*. This movement is always in the direction of the traffic. It being a double track bridge, the traffic over the north track is always west-bound, while that over the south track is always east-bound.*

The creeping is confined to the bridge proper and to the eastern approach, which is a series of short girders on iron columns. The approach is on a grade of 80 feet per mile and is 2,500 feet long. The tracks are crowning over the bridge, which is 1,600 feet long, the grade at the centre being 5 feet higher than at the abutments.

The amount of the creeping is greatest on the approach, being for the year, Sept. 1, 1883, to Sept. 1, 1884, in the ratio of 162 to 100. The ratio of the corresponding distances is approximately 156 to 100.

Various methods have been employed to hold the rails in place, but never with success. Steel spikes, bolts, straps and splice bars have been sheared off and torn asunder; frogs, crossings and connecting tracks in East St. Louis pulled out of line, and the rails themselves so buckled and twisted that when one was removed it could not have been replaced again by eight inches. Finally it was no longer considered profitable to try to hold them, for if they should succeed in holding them to the structure then these great strains would then come upon it, and this would be

* This is sometimes reversed to overcome a tendency the arches have to take on a distorted shape, in which the crown of the curve is moved away from the centre in the direction of the traffic.

more objectionable than to leave them free to move and correct it constantly by cutting out and replacing.

There is no creeping in the tunnel, though the traffic remains in a single direction, as the double track extends through to the Union depot.

Provision is now made for this movement at three points on each track, viz.: at the entrance upon the east approach, at the east abutment, and at the west abutment. On the north track, since the rails go west, openings are constantly enlarging at the approach and closing at the west abutment. On the south track the rails go east, so the openings are enlarging at the west abutment and closing at the approach. Where the openings are enlarging, short pieces of rail are taken out and longer ones put in their place, and where they are closing up, longer ones are removed and shorter ones inserted. This has to be done many times a day at each point where the rails are cut. On account of the switches located at the east abutment, it is necessary to have cut sections each side of these, making four places on each rail where this movement has been provided for. Every second day the foreman in charge of the day squad measures the movement that has occurred, on both approach and bridge, and keeps a careful record of the same. The monthly movements are copied into the reports and are on file in the offices of Mr. Wuerpel, the Superintendent of Structure, and of Col. C. Shaler Smith, the engineer of the bridge company. In these monthly reports, the movement of a given rail on the approach is added to its movement on the bridge, thus showing the work done in splicing on that rail: but these amounts must be separated again for any discussion of these movements. In Table I. the amounts were copied directly from the foremen's note books, and the true movements kept distinct.

TABLE I.

MOVEMENT OF RAILS ON THE ST. LOUIS BRIDGE AND APPROACH.

Month.	Approach (2,500 ft.).					Bridge (1,600 ft.).				
	N. track. (West.)		S. track. (East.)		Ratio: Mean north track / Mean south track.	N. track. (West.)		S. track. (East.)		Ratio: Mean north track / Mean south track
	N. rail.	S. rail.	N. rail.	S. rail.		N. rail.	S. rail.	N. rail.	S. rail.	
1883.	In.	In.	In.	In.		In.	In.	In.	In.	
September....	382	388	382	380	.99	248	250	227	227	1.10
October	408	410	434	446	.92	234	230	229	228	1.02
November ..	390	390	400	400	.97	270	270	224	224	1.20
December...	404	408	430	434	.94	272	278	240	244	1.14
1884.										
January......	398	400	410	422	.96	284	282	247	247	1.15
February.....	390	390	403	401	.97	266	271	241	241	1.11
March.........	390	388	400	400	.97	240	231	234	234	1.01
April..........	394	393	407	411	.96	239	238	241	242	.99
May	408	410	413	409	1.00	297	283	263	248	1.14
June..........	401	399	420	421	.95	269	268	255	257	1.05
July...........	406	404	416	406	.99	266	231	222	222	1.12
August........	435	437	447	446	.98	286	284	263	259	1.09
	In.	In.	In.	In.		In.	In.	In.	In.	
Year..........	4806	4817	4962	4976	.97	3211	3119	2886	2873	1.099
	Ft.	Ft.	Ft.	Ft.		Ft.	Ft.	Ft.	Ft.	
	400	401	414	415		268	260	240	239	

TABLE II.

TRAFFIC OVER THE ST. LOUIS BRIDGE FOR ONE YEAR.

MONTH.	No. engines east.	No. engines west.	No. freight cars east—loaded.	No. freight cars east—unloaded.	No passenger cars east.	No. freight cars west—loaded.	No. freight cars west—unloaded.	No. passenger cars west.	Total tonnage east.	Total tonnage west.	Ratio— West tonnage. / East tonnage.
1883.											
September	2,071	2,071	5,855	6,834	4,893	9,104	3,939	4,952	403,200	467,700	1.16
October...........	1,950	1,950	4,058	3,732	5,678	5,615	1,522	5,690	336,800	359,900	1.07
November........	2,146	2.146	4,501	6,518	4,676	9,681	1,789	4,741	362,300	463,000	1.28
December....	2,104	2,104	5,920	5,849	4,770	7,878	3,363	4,828	396,000	427,600	1.08
1884.											
January	2.245	2,245	6,697	8,927	4,747	10,994	2,309	4,798	449,200	508,900	1.13
February..........	1,976	1,976	5,729	7,449	4,258	8,158	4,313	4,275	388,900	427,700	1.10
March......... ...	2,101	2,101	7,466	6,700	4,792	8,316	4,455	4,839	445,500	419,600	1.01
April.............	1,990	1,990	6,297	6,000	4,741	6,533	4,485	4,754	402,400	394,700	.98
May..............	2,140	2,140	6,253	5,375	4,958	6,957	4,482	4,965	405,100	441,000	1.09
June....	2,109	2,109	6,322	5,787	4,996	7,498	4,328	5,017	410,200	429,800	1.04
July................	2,148	2,148	5,958	5,971	5,118	7.527	4,707	5,125	401,800	437,700	1.09
August............	2,138	2,138	5,797	6,673	5,006	9,213	3,653	5,024	405,100	472,200	1.16
Total for year..	25,118	25,118	70,853	75,903	58,633	97,474	43,345	59,011	4,806,500	5,282,800	1.099

Table II. is compiled from the records on file in the offices of the Manager and Superintendent of the bridge. The tonnage has been computed by allowing 80,000 lbs. as the weight of an engine, 55,000 lbs. as the weight of a loaded car, 18,000 lbs. as the weight of an empty freight car (they are largely coal cars), and 40,000 lbs. as the weight of a passenger car with its ordinary load. The engine weight was furnished by the Master Mechanic and the other values are the estimates of the officials of the company. From the total movement for the year, Table I., we have the following relations :

The ratios of the movement on the approach to that of the same rail on the bridge are respectively: 1.49, 1.54, 1.72 and 1.73, or an average of 1.62. The ratio of the corresponding lengths of track is 1.56. The mean westward movement for the year on the approach (up a grade of 80 ft. per mile) was 401 feet.

The corresponding eastern movement (down the same grade) was 414 feet.

The mean westward movement on the bridge was 264 feet.

The mean eastern movement on the bridge was 240 feet.

The western movement on the bridge was 110 per cent. of the eastern movement, while on the approach the westward (up grade) movement was only 97 per cent. of the eastern movement, or a difference in these west to east ratios of 13 per cent., which is doubtless due to the effect of the heavy grade on the approach, the expansion and contraction from temperature causing mostly a down-grade movement.

From Table II. we see that the ratio of the westward to eastward tonnage for the year was 1.099, while from Table I. we see that the ratio of the mean westward rail movement to mean eastward movement was also 1.099. This extreme coincidence is of course accidental, but if these percentages be compared month by month, it will be seen there is a common

law pervading both. Here on the bridge this ratio is not affected by the grade, for it is symmetrical with reference to the two movements. This identity in the ratio of the movements with the ratio of the tonnage west and east would of itself lead us to conclude that the movement is proportional to the tonnage. On the other hand, we see that the ratio of movement on approach to that on the bridge is 1.62, while the corresponding ratio of the distances is about 1.56. From this we might infer that the movement is proportional to the length of structure. The increased movement on the approach *may* arise, however, from more favorable conditions there for movement, and the close agreement in the ratio of the movements on approach and bridge, with that of their distances be purely accidental. Conclusive evidence on this point will appear below.

The St. Louis bridge is not alone in this matter of rail movement. The Pennsylvania Company had trouble on their Harrisburg bridge* over the Susquehanna, while it was still a single track. The traffic was heavier, however, going east, and the rails crept in this direction. The exact

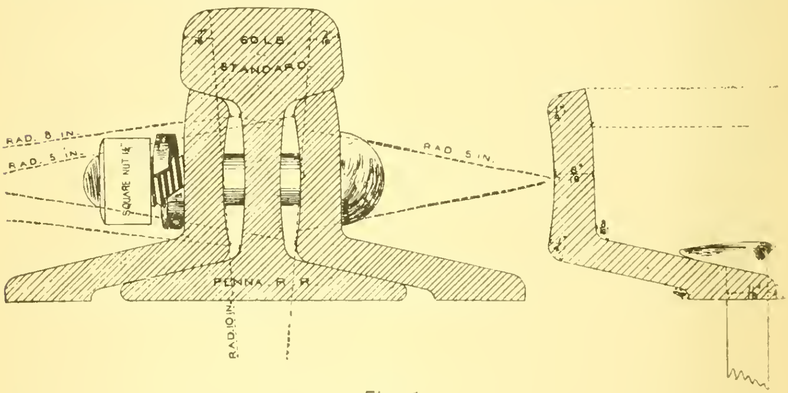


Fig. 1.

amount of the creeping was never known, but the fact of creeping was shown by the displacement of the curves at each end of the bridge, as much as four feet of track being removed from one end of the bridge and replaced at the other at one time. The movement was stopped by the use of a splice such as is shown in Fig. 1.

The splice is an angle bar which projects over the flange of the rail at bottom and rests on the tie. Four spikes are notched into the bottom flanges of a set of splice bars, and these are sufficient to keep the rail in place even now, with the bridge changed to double track and the traffic all in one direction on each track. The cause of the efficiency of this device will be referred to in discussing remedies.

Rails are always observed to creep on heavy grades, but this is probably mostly due to the expansion and contraction from temperature, and is no function of the direction or amount of the traffic. In both expansion and contraction there must be a movement on the ties, and this movement will always be in the direction of the least resistance. On heavy grades of considerable length, the least resistance will be toward

the foot of the grade, and there will be a general movement in this direction. On any line of road, where the traffic is all in one direction, there is always observed a *tendency* toward creeping, all along the line, in the direction of the traffic. The amount of such creeping is usually small and can generally be resisted.

An analagous action is the creeping of bridges on their supports. A study of this very plain case is likely to throw considerable light on the creeping of rails.

If a bridge have its two ends similarly mounted, whether both on rollers, or both on slides, when a train comes upon it from the right, this end is at once pinned fast by the weight of the train, and as the train moves over the bridge it causes a certain amount of deflection in the truss. This deflection lengthens the bottom chord and shortens the top one, so that if the truss is supported at the bottom chord, the left end moves to the left, but if it is supported at its top chord, as deck bridges sometimes are, the left end will move to the right. I have observed this movement when it amounted to as much as three-fourths of an inch. As the train goes off the truss recovers its normal position, the lower chord shortens up and the upper one lengthens out, but now the left end is pinned fast by the departing train while the right end is free to move. The recover will take place at this end, therefore, so that if supported at the bottom chord the truss is pulled forward, and if supported at the top chord it will be moved backward by an amount equal to the distortion of the corresponding chord. If it is a single track bridge, with traffic equal in both directions, its movements will compensate, and so will not crawl off the piers. If the traffic is unequal, the truss will move in the direction of the heavier traffic when supported at bottom, and against the heavy traffic when supported at top. If one end is on rollers and the other anchored fast to the pier, then, of course, the movement all occurs at the roller end, regardless of the direction of the train. I have understood that the Louisville bridge moved north from this cause by some six inches, when it was found necessary to anchor one end fast to the pier. All bridges will act in this manner when both ends are treated *alike*, whatever that may be.

Causes Assigned for the Creeping of Rails on the St. Louis Bridge.

Many causes have been assigned for the creeping of rails on the St. Louis bridge. I will enumerate some of these. with what I conceive to be the objections in each case. Some of these assigned causes are the result of no study of the facts in the case, and like most imaginary causes of hypothetical phenomena, they are either not pertinent or not sufficient to the case in hand.

1. That it is due to the grades. But the creeping is nearly as much up grade as it is down.

2. That it is due to the stopping of trains on a down grade. This at first appears plausible, for the trains generally are stopped on a down grade going west at the west abutment, which would apparently pull the rail in the same direction. and this is what is observed to occur. But these rails are continuous only over the bridge, being cut at the east abutment, and trains do not stop going west on reaching the east abutment ; therefore this cause does not explain the westward creeping, on a

stiff up grade, of the north track on the approach. The creeping on the approach being greater than that on the bridge, and wholly unaccounted for on this hypothesis, it must be rejected.

3. That it is caused by the tapping or pounding of the wheels against the rear ends of the rails, thus driving them forward. If this be true it should be the same in the tunnel, or on any ground track, as on the bridge. Again, it would appear comparatively easy to resist this action by proper holdings, whereas the tendency found to exist is almost irresistible. Besides, with the modern splice, the rails are held so nearly at the same elevation, and so close together, that it is difficult to see how very much of a blow could be given by the wheel.

4. That it is due to the deflection of the bridge itself by the train load. This is also a plausible theory, inasmuch as the track is crowning over the bridge, so that when the middle arch is compressed and lowered by the train-load, the rail must be shoved ahead a little, since the rear end must be held fast by the weight of the train. I am inclined to believe this cause is good so far as it goes, but that it does not go near far enough. For, the track is crowning, in a single curve, over the three arches, rising five feet in a distance of 1,600 feet. If now the middle arch is depressed so as to bring the track horizontal over this arch, it would cause a flattening of but one foot in the track, and this flattened track would be shorter than the normal curve by only *four one-thousandths of a foot.* The grade being straight over the end arches, any deflection of these would cause the track to sag, and so pull back on the rails from in front. The actual movement for one train is often as much as half an inch, or 40 one-thousandths of a foot. This cause does, therefore, not go far enough. Besides, it fails to account for any movement on the approach. Again, if this were the cause, the forward movement noted for any train should be observed to take place *ahead of the train*, whereas, when we closely observe the action, it is found to occur *only during the passage of the train.*

5. That it is due on the bridge to the *distortion* of the arch. When the train load comes upon the arch from one side, this haunch is flattened somewhat and the forward haunch is lifted, resulting in a forward movement of the crown of the arch. When the train goes off the flattening is on the forward side, resulting in a backward motion of the crown, but now the rail is pinned fast at the forward end of the arch, so that the arch would *slip backward under the rail*, and then, as it rights itself again, when the train has passed, it pulls the rail forward with it. If this were the explanation, which would not apply to the approach at all, then, the following actions should be observed at the pier, or abutment, at the forward end of the arch in question: First a forward movement of the rail as the train comes upon the rear half of the arch; second, a backward movement, as the train comes upon the second half of the arch, due to the arch settling back to its normal position: third, no movement under the train itself at the forward pier. After many days observations, I have been unable to detect any such action. On the contrary, the movement all seems to occur during the passage of the train.

6. That it is due to the paening of the rail. As the wheels roll along

over the rail, each one flattens out, or paens the rail somewhat, immediately under it. Most of this effect is a temporary distortion, the rail recovering its normal shape after the load has passed off ; but a small part of it is permanent, so that an old rail is somewhat longer than when it was first laid. This permanent effect is proportional to the tonnage and to the length of the track, but for the 1600 feet over the St. Louis bridge the permanent increase of length of one track would not certainly be more than a few inches for one year, whereas the movement is 260 feet. The creeping from the temporary distortion, or paening, would be much greater. This is best conceived by thinking of a heavy roller moving over a strip of india rubber. The spreading of the rubber under the wheel is lengthwise as well as sidewise, and so far as it is lengthwise, by so much will the rubber strip move forward. This effect is also proportional to both tonnage and distance. It would also be greater for a rail supported in a continuous stringer than for a rail laid on ties. It would be impossible to accurately compute this effect, but I think it must be very small.

The last three causes, 4, 5 and 6, are those assigned by Col. C. Shaler Smith, the engineer in charge of the bridge. They are all good so far as they go, but their combined effect does not seem sufficient to account for the great movements we find on the bridge, and only the last one can be applied to the approach.

A strong objection to all the causes of movement assigned above, is that they involve the actual slipping of the rails upon the ties, this slipping occurring with the first three assigned causes while the train load is on, and in two other cases occurring ahead of the train. It is quite impossible that the rail should slip on the ties, when the train load is on. For instance, in a train of twenty loaded cars, weighing 55,000 lbs. each, with a sixty-ton engine, we have 610 tons of load on the rails. If the coefficient of friction between iron and wood be taken as 50 per cent., we would have a resistance to slipping of 305 tons, or 305,000 lbs. for each rail. If we allow a strength of 50,000 lbs. per square inch for iron, rails of six square inches in cross-section would be torn asunder before these rails could be made to slip on the ties. (This cross-section is that of a 60 lb. rail.) This is also the measure of the force necessary to keep the rail from moving, which seeming paradox will be understood when the chief cause of movement is explained.

The True Cause of the Creeping.

The true cause, as the writer conceives it, of the creeping of rails due to traffic upon them, has not come to his notice, though he has no doubt but it has often been similarly explained. The explanation is very satisfactory when once examined, and carries conviction with it, but it seems to have been generally overlooked.

One will be the more ready to accept the explanation about to be offered, if the phenomenon itself be first fully described. The method of observation was as follows : Mark with a lead pencil a continuous line from the lower flange of the rail, over the head of a spike, at right angles to the rail. When a train passes, observe two things, the wave motion of the rail and the increments of forward movement every time a wave passes and the rail is again pressed down upon the ties. It was found

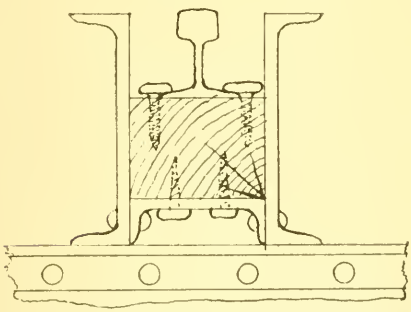
that, between the trucks of each car, the rail lifts itself free from the ties, raising a quarter of an inch or so, and when the rear truck comes along and presses the rail down at the marked sections, it has moved forward a little. There is a small wave in front of the engine, and a corresponding movement, but apparently no greater than under any single car. The wave under the car is higher, not from the heavier loads on trucks, but from there being a load both before and behind, each of which tends to lift the rail between. This upward curving of the rail is due to the elasticity of the supports. On the bridge, the rail rests on blocks of gum wood, $5\frac{1}{4}$ inches thick, which are held between 12-inch channel bars, as is shown in Fig. 2.

These pillow blocks are 17 inches long, with alternating spaces of 19 inches. The elastic action of these blocks gives the rail a wave motion *independent of the deflection of the channels.*

On the approach, the rail rests on a two-inch oak plank, laid longitudinally, this plank resting on cross-ties, 8 inches wide, with spaces of 10 inches.

On both bridge and approach, the rails are left free to move, being held together by the Sampson splice bar, being a plain bar without flanges.

Fig. 2.



The pertinent facts then are, that there is a wave motion of the rail, independent of its supports, such a wave occurring under each car and moving with it, giving a slight forward motion to the rail every time a given section is brought down upon the support. Evidently the total movement for one train varies with the weight and number of cars in the train, or with the tonnage of the train.

When the *manner* of the action is explained, the *cause* follows very naturally. The rail is held fast on the ties *on its extended side.* This causes the rail to measure its length across the bridge on its extended flange. If but one wave of this sort passes over the bridge, the effect is cumulative, and the movement increases with the length of the bridge. If a series of waves pass, the effect of all waves after the first is a constant quantity. A detailed explanation may be given by the aid of Fig. 3.

For simplicity, let the depression be caused by a single wheel at P, moving toward p. Let pp' be a vertical section parallel to PP'. On account of the deflection of the rail, the normal section at n' is oo', the lower fibres being extended from $P'p'$ for a horizontal position to $P'o'$ for the deflected condition. In other words, the point o' has moved forward from p' as a result of the deflection, the point P' being fixed by being held fast to the support by the load. As the load moves toward p the depressed portion of the wave moves with it, and when the load

reaches p the normal section oo' has come to coincide with the vertical section *pp′ by revolving about o′ as the fixed point.*

The secret of the whole matter is, that the rail rolls itself across the bridge on its outer, or extended side, and by as much as this is longer than the neutral axis, by so much it will creep for a *single* wave passing. This amount is directly proportional to the length of the structure, and to the amount of the deflection. If another wave follows this, however, its additional effect will be constant, and will not increase with the length of the structure; in other words, this and all succeeding wave effects of the series will be directly proportional to the deflection alone. The total train effect will therefore be proportional to the weight and number of cars passing—in other words, to the tonnage of the train. This has been seen to be true on the bridge. On the approach the effect of the grade comes in to modify this ratio.

From the above reasoning it is evident that if the rail were supported at a point above the neutral axis, as under the head, for instance, there would be a tendency to creep backwards, or against the direction of the

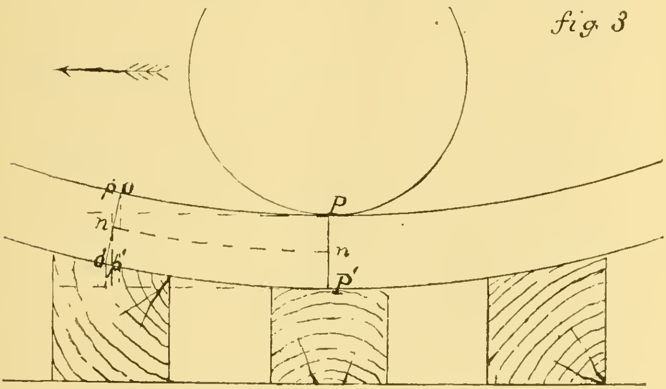


fig 3

traffic, from the compression of this upper side. There would still be a forward tendency, however, due to the wave motion of the rail, inasmuch as the neutral line of the rail, when thrown into waves, is longer than the corresponding linear distance. If the rail be supported from the upper surface, as has been done in the model to be exhibited, then the backward motion due to the compression of the upper flange would more than counterbalance the forward motion due to the waves in the neutral axis, and the rail would actually move backward.

If these opposite actions can be shown to occur, as here described, then there is evidently a point of suspension somewhere between the neutral axis and the upper surface, from which, if the rail be suspended, there will be no tendency to move either forward or backward.

Some English rails are supported from the lower side of the upper flange, or head, and it is said their tendency to move forward is much less than that of the American rail.

It may be objected to this theory that this action obtains on the ground as well as on bridges and trestles. True, it does; and there is also a strong tendency to creep on the ground, but not so strong but it can be

resisted. This is on account of the yielding nature of the soil and ballast. If the ties were fastened as rigidly to the ground as they are to bridges and if the wave motion were as great, the tendency to move in the direction of a continuous traffic would be quite as great.

It is evident that it is not the absolute deflection of the rail that is significant, but the wave motion of the rail independent of the motion of the supporting track system. If the rails were fastened down snug upon the stringers, so that they deflected with them strictly, the rail would have no tendency to crawl upon the stringer. In the case of the Pennsylvania bridge, at Harrisburg, the splice bars fit snug under the head and rest on the ties, so supporting the rails, at the ends at least, above the neutral axis. Each set of splice bars is also held in place by four spikes, making four spikes to each rail that would have to be sheared off in order to move the rail. The rail would evidently slip on the ties, with its load on, before it would do this. When the attempts were made to hold the rails on the St. Louis bridge, the holdings were concentrated at isolated points on the line, so that the crowding action accumulated for a considerable distance, and the holdings gave way before this longer reach of rail would slip on the supports with the loads on. If each rail were held independently, as is done on the Harrisburg bridge, the creeping could probably be stopped on both the bridge and approach, but it is feared this would bring too great a strain on the truss members. The solution offered above, of supporting the rail under its head, would be a more satisfactory method of treatment, inasmuch as it would utterly destroy the *tendency* to move, and hence there would need be no strains introduced by spiking it fast. The time of eight men is now mostly occupied (five by day and three at night) in correcting the movement, as it occurs in the St. Louis bridge, but it is claimed this is no expense to the company, as they would have to keep so many trackmen in employment anyway, and they might as well be kept busy. It would seem, however, that a considerable portion of this expense could be avoided by wholly stopping the rail movement. The only way of doing this without straining the structure is by destroying its *tendency* to move, and this can only be done by supporting the rail above the neutral axis, or else in such a manner as to destroy its independent wave motion.

From the above explanations, one can understand the seeming paradox, that the rails creep a foot a day, and yet do not slip on the ties. And further, that to hold them in position when supported on the bottom, they must be made to slip on the ties when the load is on, and the force necessary to cause them to do this is the measure of the force required to hold them in place.

In the fore part of this paper the striking coincidence of relative movements and relative lengths of track on bridge and approach was noted, but not explained. Two possible causes were suggested, and, in fact, both are found to act. Of the many waves formed in the rail by the passage of a train, only the small wave in front of the engine is cumulative in its effect, or has its effect of translation directly proportional to the distance traversed. The others all have a constant effect. This would, therefore, have little influence, and if this cause

acted alone, the movement ought to be about the same on bridge and approach, regardless of their relative lengths. The other cause, viz., more favorable conditions for movement on the approach is more effective, inasmuch as here the rail rests directly on a continuous stringer laid on top of the ties, while on the bridge it rests on isolated blocks, with intervening spaces of 19 inches each.

In the case of the stringer there is no giving in the supports, in a longitudinal direction, for it is pinned fast at intervals, and is a continuous member. In the case of the blocks, they doubtless do yield slightly in a longitudinal direction, even under the load, and then recover again, as the rail lifts from them between the depressed portions of the track. The rail does not, therefore, move so much forward on account of a sort of backward rocking of the blocks. This same condition of freedom to rock back and forth a few hundredths of an inch obtains on all land-track systems, and so the movement of the rail is easily resisted. In the tunnel the rail is laid on a stringer also, but it so large as not to deflect appreciably, and as the rail is spiked close to this stringer, it can have no independent wave motion, and so has no tendency to creep.

[*Note.*—On the occasion of the reading of this paper before the St. Louis Engrs. Club, a working model was exhibited which furnished an ocular demonstration of the theory herein advanced for the cause of the creeping of rails. A circular track composed of a wooden rail 1 inch deep by ½ inch wide, made of hickory, rested on 16 radial ties which were supported at the outer ends by springs of coiled wire. These outer ends were held rigidly against any lateral motion, but were free to move vertically. The rail was not fastened to these ties but simply held in guides that kept it in place, concentrically, it being free to take on an independent wave motion, and to move longitudinally around the circle. On this track a car was made to run. The car consisted of a plank forming a diameter to the circle, with a wheel at each end. A vertical axis at the centre held this plank in position while it was free to revolve horizontally. This plank was then loaded with some four hundred pounds, and made to move around on the track. The track was thrown into two great waves, being depressed about an inch below its normal position under the wheels, and raised about the same amount above the ties on the other quadrants. The rail was found to move rapidly in the direction of the motion of the car, so that when the car had completed three revolutions the track had moved one inch. This was the case in whichever direction the car was moved.

Thus far the experiment had only proved what has already been observed on the bridge. In order to show that our explanation was the correct one, it became necessary *to suspend the rail from the upper side*, to see if the rail would then move *against* the motion of the car. This was done by screwing iron plates to the top of the rail, allowing them to project over the sides and then supporting these on blocks. The rail was now hung from its upper surface, and, according to the theory herein advanced, it ought to move backwards. *This it was observed to do, whatever the motion of the car.* The amount of the backward motion now was not as much as the forward motion when supported on the bottom, as indeed, it was not expected to be, on account of there being a forward tendency in both cases, of an amount equal to the excess in length of the contorted neutral axis over its projection on the horizontal plane. The compression of the upper fibres being more than the excess in length of the contorted neutral axis over its projection, the rail moves backward by this much. If the fibre could be found, somewhere above the neutral axis, whose compression would just equal the above neutral axis excess, then the rail would have no tendency to move in either direction.]

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

THE METRIC SYSTEM AND OUR SOCIETY.

By Albert H. Howland, Member of the Boston Society of Civil Engineers.

[Read October, 1884.]

Though our Society has printed since its revival and reorganization in 1874 a hundred or two pages of the statements and appeals of the advocates of the metric system, it has never had a discussion of the *merits* of that system. It committed itself hastily and inconsiderately in its favor in 1875; this it did immediately on the report of a committee all of whose members were zealous partisans of that system, and our metric committee has always been similarly composed; consequently its reports, though intended to be ever so fair, may properly be considered ex-parte statements.

Previous to 1879 there had been no article in our Constitution restricting the Society's action in respect to giving its indorsement to propositions of any kind. Consequently, as ten is a quorum, the fact of its having taken such action is not evidence of the approval of more than six members. The friends of the metric system have generally objected to making public the votes taken regarding it. In 1879 the following article was added to the Constitution: "No proposition which includes the Society's indorsement shall be passed except in the same manner as prescribed for amendments to the Constitution," So that since that date its attitude has been that of impartiality and it has become the practice to print the reports of the Metric Committee without reading them at the meetings. A portion of our members have always been urging the Society to engage in the advocacy of the metric system. They want this Society to be a kind of a missionary organization for the dissemination of their belief and the accomplishment of their purpose. In the fall of 1875 we were asked to sign an agreement to use only that system in our practice after the Fourth of July following and so begin the new century with a clean sheet. I think it was stated that nearly all the architects in the cities in this vicinity had signed it. When the question was first brought into the Society it was urged to send a committee to Washington to press upon Congress the introduction of the system. At one of our meetings a confession of "Faith in the Metric System" was read, forming a creed of some 20 articles, one of which was in substance that the people of this country should be forced to use the metric weights and measures. Recently an attempt was made to have the Constitution amended by inserting the characters "80 Km." in one of its articles in place of the words "fifty miles."

Now, it seems to me very plain that any society which is to engage in advocacy of a cause, in a missionary enterprise, in seeking to make proselytes to a creed, or in other similar course, should be so constituted as not to admit unbelievers to membership. Its creed, belief, dogma, or whatever you please to call it, should be a part of its *organic law*, and be

expressed plainly, too, not tucked away in a sly corner or left to inference: all members should be required to subscribe to it and promise to be faithful; in short, the organic law should have an automatic cut-off which should separate the goats from the sheep. Otherwise, as long as mankind are finite and fallible, the society will be liable to have one creed at one time, and a directly contradictory one at another. In fact, such an oscillation may depend upon fluctuations in the relative degree of absenteeism in two classes of members, the "moss-backs" and the "kids."

It is very questionable policy for a society that is not organized on such a basis as I have referred to, which I may call a missionary basis, to give the use of its name and prestige to a portion of its members to advance a cause that they have espoused. If it does so, it is only just to other members to allow them similar privileges. This leads to wrangling and disputes and turns the society into a mere debating club in which points of parliamentary practice become more important than the chief concerns of a civil engineers' society; it leads to the resort to methods and practices that may be willingly submitted to by those in sympathy with this object but be distasteful to others. The doctors have had valuable experience in this respect: they are divided on the question of a creed (similia similibus). In short it is best for this Society in its *action* to steer pretty clear of matters of opinion, belief and dogma. I would instance a precedent that ought to be very convincing to the friends of the metric system: in the midst of the recent cholera panic the French Academy of Sciences was asked by the government to give its opinion as to the cause of the cholera; it replied that it was contrary to its policy to give opinions.

I am not maintaining that the Society should lay down a cast-iron rule that it will never make recommendations or act on matters of opinion, but at least it should not be precipitate in indorsing the opinions that the advocates of a cause may bring before it, but should first make a thorough and impartial investigation. It would seem appropriate, too, that its principal activity in that way should be directed to questions that are essentially engineering ones, which the question of weights and measures is not. Those of our members who favor the metric system can petition Congress as much as they please, either as individuals or as members of this Society; but they seem not to be satisfied unless they can use its name in such a way as to carry with their own influence that of their opponents.

We shall do well to note the action of the American Society of Civil Engineers, which after giving the metric advocates a hearing and after listening to and reading the discussion voted nearly two to one to indefinitely postpone the whole question. The metric committee of the Civil Engineers' Club of the Northwest, after long consideration said in their final report, "We do not see that it can be forced by legislation upon an unwilling or even indifferent and uninformed people." I would suggest as a subject for reflection the question, how long a period is likely to elapse before the number of legal voters in the United States who are indifferent and potentially unwilling will become so small that they will not have to be reckoned with.

Prof. Hilgard, of the Coast Survey, officer in charge of the government standards, though formerly honored as a shining light by the advocates of the metric system, recently said that he doubted whether that system would *ever* wholly take the place of all others in our domestic transactions.

One of the objections to attempts to introduue it here is that improvements that can be easily made in our present system (so called) are thereby delayed and the laws lag in sanctioning improvements that actual practice has brought about in spite of laws; such for instance as the use of the ton of 2000 lbs. and the cental of 100 lbs. There are several features in our system that are treasured as precious relics by the advocates of the metric system, such as our barleycorns, roods, and gross tons; it will be interesting to note their course in reference to this latter.

The metric system looks attractive: it has lots of theoretical perfections that are practically useless or worse, and I feel confident that it is some of its real defects that have secured to it many of its devoted friends in this country. Reflect on its whimsical unspeakable polysyllabic Græco-Roman nomenclature: its spell doubtless fascinates many a mind of classic culture (in spite of its hybrid character), especially if there was a youthful aversion to mathematics; he feels that his boyhood's days were embittered by reduction ascending and descending, and here is escape for posterity in the mystic combinations of centi and kilo.

What the iron heel of a military despot may have accomplished with the pauper laborers of an effete European monarchy is not worth a tinker's dam [this orthography is used on the authority of an ex-governor of our State] as a precedent for a free people; and it may be safely assumed that they will use about such weights and measures as they please, whatever laws may be passed and however eager the classes that *don't* do the weighing and measuring may be to impose their reform on the classes that *do*. The prospect is that this reform will be pushed till it becomes so obnoxious that it will be smashed, leaving relics here and there that will be more out of harmony with common practice than anything in our present system, and so will but intensify such discord as exists.

The extravagant claims of the metric advocates I consider grossly deceptive. Incidentally, I would mention as a slight corrective some figures cited at the Meridian Conference at Washington the other day:

Tonnage controlled by Greenwich standard........	14,000,000
" " " Paris "	1,735,000

Of course these figures, to have their accurate significance assigned them, would require analysis (which I have not at hand); as much perhaps as the metric claims.

Unusual efforts seem to have been put forth lately to manufacture a great metric boom; its features are soon likely to be disclosed; the machinery works beautifully; still booms may come and booms may go, but our people are about as likely to discard their habits of thought and action regarding weight and measures (which to vast numbers are practically almost a part of their own being), as they are to set about training themselves to become ambidexters.

DETERMINATION OF THE MECHANICAL EFFICIENCY OF A GRAMME GENERATOR AND MOTOR.

By Francis E. Nipher, Member of the Engineers' Club of St. Louis.

In some recent determinations of the mechanical efficiency of an electrical generator and motor, the plan of investigation was somewhat peculiar by reason of the fact that the engine used to drive the generator could not be kept at a constant speed when the load on the motor was varied. Some interesting features were developed which are here presented.

The motor was a one-light Fuller machine, having the armature and field connected in series, and the generator differed from it apparently only in the wire wound upon the armature and field magnets, the resistance of the generator being about fifty per cent. greater than that of the motor. The amount of iron in the two machines was apparently the same. The resistance of the line connecting the two machines was one-tenth that of the combined resistance of the two machines.

The generator was mounted on a Brackett dynamometer which served to measure the power delivered to the pulley of the generator. As this dynamometer may not be known to you all, it may be well to say briefly that it consists of a cradle upon which the generator is mounted, the cradle being supported on cone points which are in the line passing longitudinally through the shaft of the dynamo or generator. The centre of gravity of the cradle and dynamo is a very little below the line of support, so that the cradle with its load is easily turned upon the cone points. When power is applied on the pulley of the generator, the attraction between the field magnets and the armature tends to turn the cradle upon the cone bearings, and this turning is prevented by a sliding load hung on a lever attached to the cradle. The load, the length of its arm and the speed of the dynamo being determined, the power applied is estimated as in the case of the Prony brake.

The power delivered on the driving pulley of the motor was determined by means of a Prony brake in the usual manner.

The motor was first run at various speeds with no load upon its pulley, and simultaneous determinations of the speeds of the motor and generator were made. Loads L of one, two, three, four and five pounds were then successively hung on the brake arm, on a leverage of one foot. For each load the speeds of motor and generator were varied between as wide limits as practicable and simultaneous determinations of speeds, loads and brake-arms were made. The relation between the number of revolutions G of the generator and M of the motor per minute for each load were expressed by an equation of the form

L	a	b
0	260	0.565
1	275	0.620
2	322	0.653
3	400	0.655
4	500	0.660
5	600	0.690

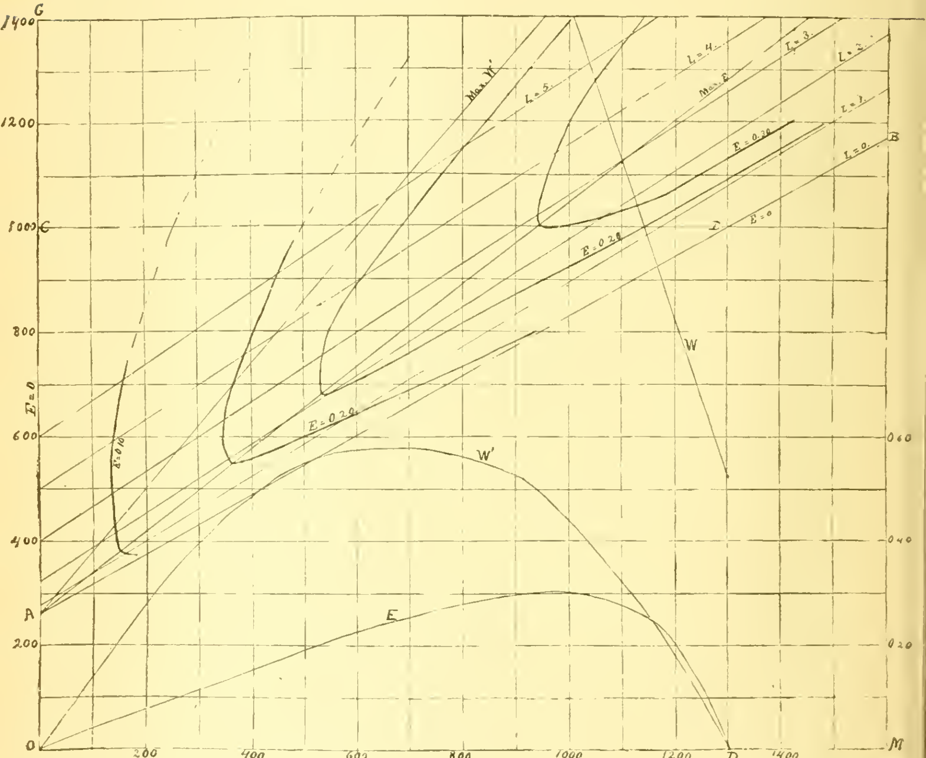
$$G = a + b\,M \qquad (1)$$

in a very satisfactory manner. The accompanying table gives the values of a and b for each value of L.

The value a, of course, represents the speed of the generator, when the

motor, loaded with L pounds on an arm of one foot, is just on the point of starting, while b is the increase in the value of G for each unit of change in M. The lines represented by these six equations are shown on the diagram.

If the rate of work of the motor corresponding to simultaneous values of M and G be laid off at right angles to the plane of $G\ O\ M$, the three variables determine a surface. This surface intersects the plane of $G\ O\ M$, in the lines $G\ A$ and $A\ B$. The work delivered by the motor is zero along the line $G\ A$, because the motor does not revolve; and it is zero



along the line $A\ B$, because the motor carries no load. For a constant value of G, the useful work per minute increases and reaches a maximum, since, while the load increases, the number of revolutions diminishes. For example, if $G = 1{,}000$, the number of revolutions per minute for each of the six values of L is determined from equations (1). These values of M are given in the table below. When these values of M and L are plotted, it is found that the points thus determined are in a straight line, having the equation:

$$M = 1309 - 138\ L \tag{2}$$

$G = 1{,}000$ revolutions per minute.

LOADS OF MOTOR ALWAYS ON ARM r OR 1 FT.

L	M	W' (H. P.)	W (H. P.)	E
0	1,309	0.000	0.525	0.00
1	1,169	0.222	0.925	0.24
2	1,038	0.395	1.325	0.30
3	915	0.522	1.700	0.30
4	757	0.575	2.080	0.27
5	580	0.552	2.500	0.22
6	480	0.54	2.89	0.19
7	340	0.44	3.28	0.13
8	200	0.31	3.68	0.08
9	67	0.10	4.07	0.02
9·47	0	0.00	4.25	0.00

By means of this equation, the remaining values of M for loads of 6. 7, 8 and 9 pounds on the motor are calculated, and it is also found that for a load of 9.47 pounds, the value of M becomes zero. The work of the motor per minute in horse-power is thus readily determined and is given in the third column of the table above.

Multiplying the equation (2) through by $\frac{2\pi r L}{33,000}$ it becomes

$$W' = K L - K' L^2 \qquad (3)$$

$$\text{where } K = 1,309 \frac{2 \pi r}{33,000} = 0.249$$

$$\text{and } K' = 138 \frac{2 \pi r}{33,000} = 0.026$$

If, however, equation (2) be multiplied through by $\frac{2\pi r M}{33,000}$ the resulting equation reduces to

$$W' = \frac{K}{138} M - \frac{K'}{(138)^2} M^2 \qquad (3')$$

The condition of maximum power may be obtained from either of these equations. From the former we obtain

$$\frac{d W'}{d L} = K - 2 K' L = 0, \text{ or}$$

$$L = \frac{K}{2 K'} = \frac{1,309}{2 \times 138} = 4.74$$

Here 1,309 is the number of revolutions of the motor when $L = 0$, and 138 is the decrease in the value of M for each additional pound added to L. on a pulley of 24 inches diameter. when $G = 1,000$.

It will be observed that the load which gives the maximum power is one-half the load which will bring the motor to rest.

From equation (3′) we also have

$$\frac{d W'}{d M} = \frac{K}{138} - 2 \frac{K'}{(138)^2} M = 0,$$

$$\text{or} \qquad M = \frac{1309}{2}$$

or the speed giving the maximum power is one-half the speed which the motor has when $L = 0$. The curve represented by equation (3′) is shown at the bottom of the diagram, and represents a section through the surface of useful work along the line $C\ D$.

It follows that the maximum power for varying values of G all lie in a common plane at right angles to the plane of $G\ O\ M$, the trace of which on

the latter plane is represented in the diagram by the line marked "Max. W'." The equation of this line is

$$G = 260 + 1.130\ M \tag{4}$$

where 260 is the speed of the generator when the unloaded motor is just on the point of starting, and 1.13 is twice the increase in the value of G per unit of increase in M when $L = 0$. In other words $\frac{d\ G}{d\ M}$ for the line marked "Max. W'" is twice the value of the same quantity for the line marked $L = 0$.

To determine the work applied on the pulley of the generator running at a speed of 1,000, when L the load on the motor is varied, the total work on and speed of the generator were plotted for each of the six series of experiments made. Each series (L being constant) gave a curve which was sufficiently regular so that in each case the work per minute (W) when $G = 1{,}000$ could be determined with sufficient precission. These values are given in the fourth column of the table above. The relation between W and L for $G = 1{,}000$ was found to be accurately represented by the equation.

$$W = 0.525 + 0.394\ L \tag{5}$$

By means of this equation the values of W for higher values of L were determined, as shown in the previous table. It is thus seen that 0.525 horse-power is applied to the generator when the motor carries no load. This work is expended in revolving the two armatures against the friction of bearings and brushes, and in heating the machines and line. If the motor were held still by a load of 9.47 pounds on a twenty-four inch pulley, G being 1,000, the power applied becomes 4.26 H. P., which would be converted into heat and would destroy the machines. This last equation does not hold for negative values of L, or where power is applied to the motor in giving it a higher speed than that given to it by the current from the generator. At some speed M above 1,309, the back current generated by the motor would exactly balance the direct current of the generator running at 1,000, and at a still higher speed of M, the current being supposed reversed, the motor, running as a generator, would drive the generator running as a motor without load, and without the application of any power from the engine. In this case $W=0$. As before observed, equation (5) cannot be used in determining this speed, which corresponds to some negative value of L, since it is an empirical equation and cannot be applied beyond the limit $L = 0$. The value of W can, however, be determined in terms of M for $G = 1{,}000$ by solving (2) for L and substituting its value in (5). We thus obtain:

$$W = 4.26 - 0.00286\ M. \tag{5'}$$

an equation which holds between the limits $M = 0$ and $M = 1{,}309$, as is the case with (5). The line represented by equation (5′) is plotted in the diagram, and is marked W.

Equations of this form are therefore applicable in such cases as are ordinarily met in engineering work, and are advantageous by reason of their simplicity.

Before leaving this part of the subject I wish to remark, with reference to the special case already discussed, where $G = 1{,}000$, that when the motor, acting as generator, is driven by the engine at a higher

speed than that at which it will drive the unloaded generator at 1,000, the generator must be loaded in order to preserve this speed. The rotations of both machines will still be in a positive direction, but the loads on both machines have become negative, and hence both W and W' will become negative. Moreover, the curve marked W' in the positive sheet of the surface, representing useful work delivered by the motor at a constant speed of the generator, will continue through the negative sheet of the surface, where it will represent total work applied to the generator, with the condition of a fixed speed in the motor. What was in the first case the motor, has become the generator and *vice versa*. In the latter case, the section through the negative surface of useful work does not show a minimum, as it does in a direction at right angles thereto, the load L being the only variable element in the quantity. The discussion of the relations of the positive and negative sheets of the surfaces, representing the direct and reverse action of the couple, however, lies outside the aim of the present paper, and is reserved for another occasion.

The mechanical efficiency of the couple, the generator and motor, is

$$E = \frac{W'}{W} \tag{6}$$

The value of E for $G = 1{,}000$ is given in the fifth column of the table above, and the curve marked E is plotted at the bottom of the diagram.

The analytical conditions of maximum efficiency for constant value of G are easily deduced, either from equations (3) and (5) or from (3′) and (5′). From the former we have

$$E = \frac{K\,L - K'\,L^2}{W'' + A\,L} \tag{7}$$

where W'' is the work applied to the generator when the motor carries no load. The condition of maximum efficiency is

$$\frac{d\,E}{d\,L} = \frac{(W'' + A\,L)\,(K - 2\,K'L) - (KL - K'\,L^2)\,A}{(W'' + A\,L)^2} = 0$$

Hence

$$L = -\frac{W''}{A} \pm \sqrt{\frac{W''}{A}\left(\frac{K}{K'} + \frac{W''}{A}\right)}$$

By reference to the remarks following equation (3) it will be observed that

$$\frac{K}{K'} = \frac{B}{C}$$

where B is the value of M when $L = 0$, and C is the decrease in M per pound of increase in L. Hence the last equation becomes

$$L = -\frac{W''}{A} \pm \sqrt{\frac{W''}{A}\left(\frac{B}{C} + \frac{W''}{A}\right)} \tag{8}$$

where the negative value of L must be discarded for reasons before given.

Substituting the numerical values corresponding to $G = 1{,}000$, the condition of maximum efficiency is found to be $L = 2.46$.

From equations (3′) and (5′) we have also

$$E = \frac{\frac{K}{C} M - \frac{K'}{C^2} M^2}{W''' - D M} \tag{9}$$

where W''' is the power applied to the generator running at a fixed speed when the motor is held still, and D is the decrease in the power thus applied per unit increase in the number of revolutions of the motor, the condition of maximum efficiency is

$$\frac{d E}{d M} = 0, \text{ from which}$$

$$M = \frac{W'''}{D} \pm \sqrt{\left(\frac{W'''}{D}\right)^2 - \frac{W'''}{D} B} \tag{10}$$

where the larger value of M is to be discarded.

Substituting the numerical values for $G = 1{,}000$ we have $M = 971$.

The formulæ given in this paper are of course empirical, but they apply with sufficient precision to the speeds which it is feasible to give to dynamos and motors, and have the merit of being exceedingly simple. While they cannot claim the theoretical importance which attaches to those recently given by Clausius,* they are much more convenient, and apparently are as precise numerically.

It is of course understood that the mechanical efficiency reached in the electrical transmission of power is only one of the elements involved in discussing the question. In comparing different methods of applying power, the real thing of interest is not mechanical efficiency of electrical or steam machinery, but the amount of useful work to be obtained for a dollar, taking into account the interest on the investment and the cost of operation. In some cases, as in elevated railroads, these latter elements are, perhaps, even more important than the matter of efficiency, as has been well pointed out to you by Dr. Adams.

INTERLOCKING.

By Isham Randolph, Member of the Western Society of Engineers.

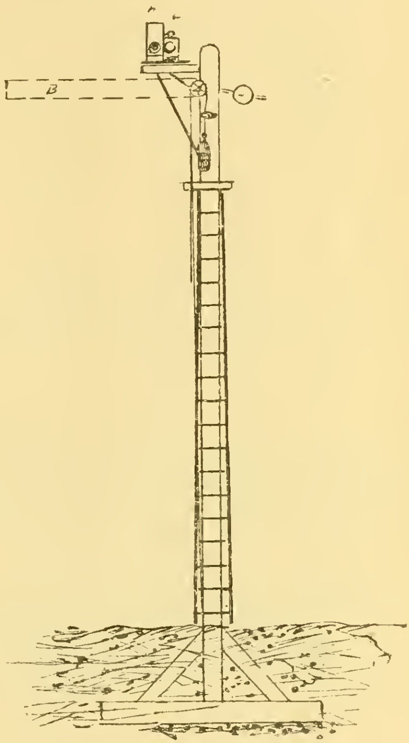
[Read September 16, 1884.]

Complying with the wishes of this Society, as expressed by a vote, requesting me to give in writing the substance of my remarks explanatory of the models and drawings which I submitted for the consideration of the members present at our 194th meeting, I offer the following:

The particular branch of interlocking which we have to consider is that of switches with semaphores. On our lines (the C. & W. I. and the Belt Railway of Chicago) there are numerous points where cross-over tracks and yard connections with main tracks, etc., etc., need the kind of protection which we are about to consider. This protection could be afforded by some one of the many expensive methods now offered to the railroad public, but the attendant outlay deterred our people from adopting any of these. In view of our needs, my mind became very much absorbed with the problems involved, and my inventive faculties were bent to the

* *Philosophical Magazine*, January and February numbers, 1884, and supplementary number June, 1884.

task of supplying the long-felt want. I think that I have succeeded in my efforts to devise mechanism simple, positively reliable in its action and economical in cost, as demonstrated by actual tests extending through many months. I will not weary you with a recital of the steps which led up slowly and laboriously to these results, but will at once state in brief what I set out to accomplish, and then turn to the drawings. I desired to protect one or more switches with a single semaphore, using but one connecting cable and contriving the levers which operated the semaphore by means of this cable so that when the semaphore showed safety, or a clear main track, the switches leading into said main track should be locked by the lower extremities of the levers; making it necessary when it was desired to set any one of the switches along this single cable for side track or cross-over to pull a pin, which act should release the lever and permit the semaphore to go to danger and unlock the switch where the pin was pulled. Next, the act of changing the position of the switch must so engage the lever in its new position as to make it impossible to draw the semaphore blade back to the position of safety until the switch is again set for the main track, when the lever may be drawn back and made fast with its pin again, locking the switch in its position for a clear main track. Now let us turn to the drawings.



Side View of Semaphore.

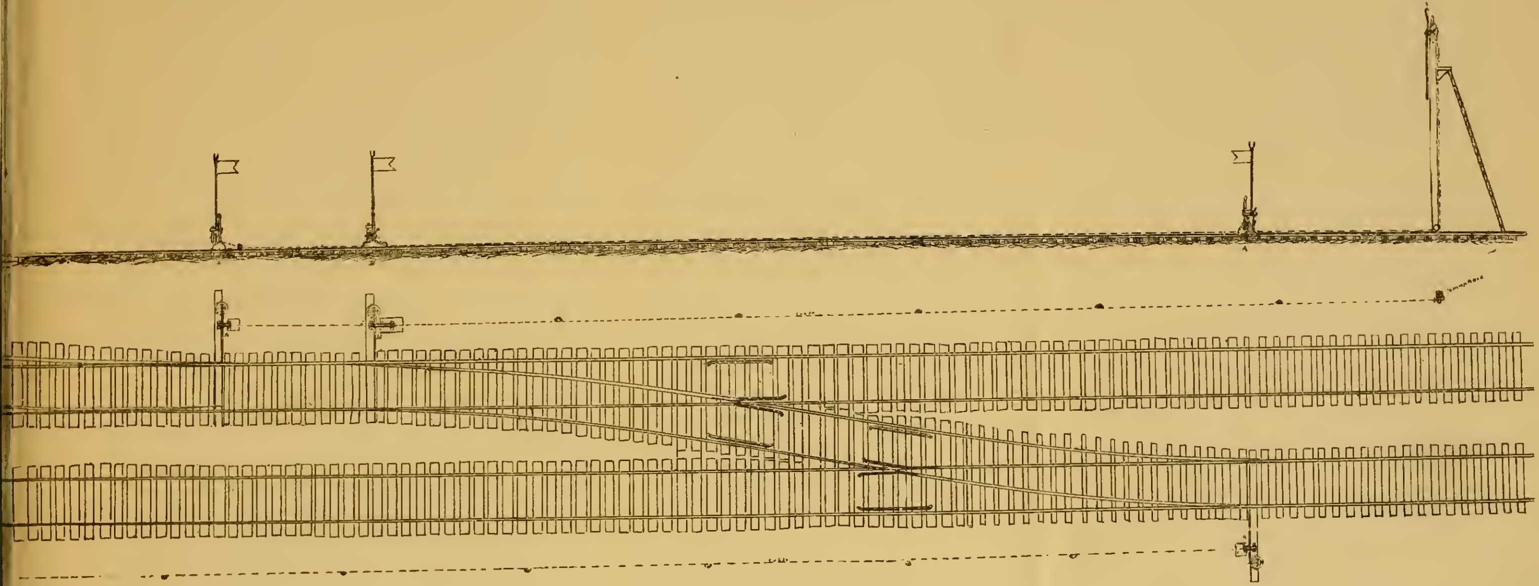
EXPLANATION.—The shaft to which the blade B is fixed is operated by a sprocket wheel. The cable extending from the switch lever fastens to a link belt passing over the sprocket wheel, and weighted so that when the lever at the switch is released, the blade is raised by the weight to a horizontal position, and the platform upon which the lamp L rests is pushed forward until it is beneath the hood H, and the light shining through the red lenses of the hood gives the danger signal.

Those upon the larger scale ($1.2'' = 1'$) show in plan and side view the mechanism and application of levers, triggers and hooks, while the small plan and side view (scale $\frac{1}{16}'' = 1'$) illustrates the whole system as applied to a series of switches. The arrangement at the end of the cable farthest from the semaphore is shown at A (see side view, large scale). L is the lever in its vertical position, with the end below the fulcrum engaged by the lugs l l on the switch rod R (see plan for position of lugs on rod). The withdrawal of the pin from p frees the lever, which is drawn forward to

the position L' (shown in dotted lines) by tension exerted upon the cable by weights attached at the semaphore end thereof. This leaves the switch free to move; if the movement of the crank is in the direction indicated in plan A, the switch rod in passing from the position R to that indicated by the dotted lines R' strikes against the pall or trigger T and throws it forward into the position T', so that it engages the notch shown in the lever just above its fulcrum, securely holding the lever in the position L' and making it impossible to draw the semaphore blade back to the vertical or safety position. If after drawing the pin from p the switch crank had been turned in the direction opposite to that just described as R'' in B, the rod would have engaged the hook H in its position H', which is equally effectual in preventing a movement of the lever back to its vertical position. The turnbuckle $T\ B$ is used to adjust the length of the cable to meet the variation caused by changes of temperature.

We now pass to the second switch at B with its apparatus. The arrangement of lugs, trigger and hook is identical with that just described at A. The difference between the rest of the device and that just described consists in the shape of the case inclosing the mechanism and the addition of sheaves 1, 2, 3, arranged in the form of a triangle. The lever L is cleft to receive the sheave 2. The use of these sheaves is simple in the extreme. The cable passes from A, as shown, beneath the sheave 1, upward and over sheave 2, downward and under sheave 3, thence onward to the semaphore; unless there be intervening switches requiring protection, in which case each switch is fitted with a duplicate of the device shown at B, and, as in that case, the cable is rigged to play over the sheaves and thence onward to the semaphore. When the pin is drawn at A and the lever drops forward to the position L', the cable plays freely over the sheaves 1, 2, 3. When, however, the switch at A remains set for the main track, and it is necessary to use B, the pin is withdrawn from p (as in the first instance at A), and the lever L with its sheave 2 falls forward to the position L', forming a second triangle having the same base and lesser altitude, thus giving sufficient slack to the cable to permit the semaphore blade to rise to the horizontal. Thus each switch is made mechanically self-protecting, and any person using the switch is obliged to set the mechanism which affords protection in motion before he can change its position from that of safety for the main track.

At the time I exhibited my drawings and models my actual test of these devices was confined to one locality where the conditions were just those illustrated in the drawings, two switches and one cable connecting with the semaphore. Since then at Auburn Junction (Seventy-fourth street), I have connected four switches upon a single cable, and they are now in successful operation. What the limit, as to number, of switches that may be protected by this method is, I am as yet unable to report. At some future meeting I hope to lay before you further results of my labors in this field of invention, as I have perfected a system of interlocking levers for the protection of railroad crossings and other similar places. In this I have utilized for my purposes principles which, so far as my knowledge goes, have never been applied to this work before.

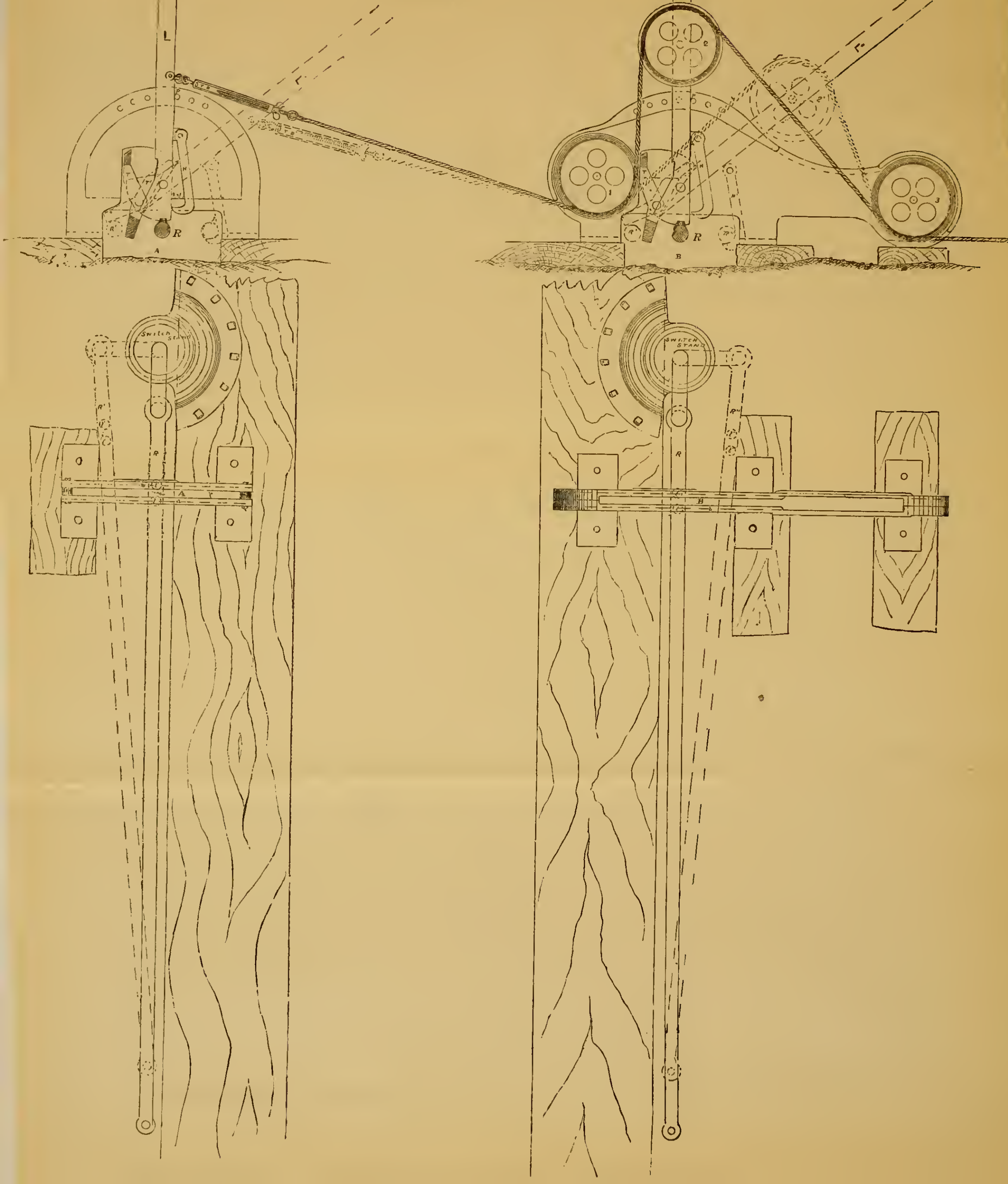


RANDOLPH'S SYSTEM OF INTERLOCKING—GENERAL VIEW.

Plan and Side View of

LEVERS FOR OPERATING SEMAPHORES AND INTERLOCKING WITH SWITCHES.

Isham Randolph, C. E.



The semaphore I use is also of my own devising, as nothing in that line with which I was acquainted exactly answered my purposes.

[NOTE.—The scale of the drawing of the mechanism of the levers, etc., was reduced arbitrarily, and the author is not responsible for the awkward ratio or for any slight inaccuracy.]

INDEX DEPARTMENT.

It is proposed to furnish, in this department, as complete an index as may be of current engineering literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value.

All readers of the JOURNAL are requested to aid in making the index as complete as possible. All notices for this department, and all matter to be here indexed, should be sent to J. B. JOHNSON, Manager Index Department, Washington University, St. Louis, Mo.

Appliances designed and used in connection with the Tennessee River Improvement, viz.: *Derrick Winch* that lowers rapidly; *Derrick Grapple, Portable Drill*, for use on iron lock gates; *Iron Canal Lock Gates* with solid and with trussed girders; *Balanced Wickets* designed to prevent leaking; *Inexpensive Switching Locomotive; Tests of Wooden Beams*, to show effects of notching and mortising, with important results: *Apparatus for testing the Strength of Explosives*, being simple and inexpensive. All these described and illustrated. Rep. Chf. of Engrs. U. S. A., 1883 v. II., p. 1483.

Bank Protection; methods pursued on the Missouri River, with many cuts showing mattresses in process of construction, mattress boats, etc. Rep. Chf. of Engrs., 1883, v. II., p. 1297.

Bow Girders (Trussed Arches), hinged at crown and springing, maximum strains in. By Emmerich A. Werner. Graphically and analytically treated. Van Nostrand v. 31, p. 320 (Oct., 1884).

Calculating Instrument, or Cylindrical Slide Rule, a pamphlet of 70 pages, by Edwin Thatcher, describing a patent device for treating numbers to four significant figures, with rules for its use. Van Nostrand, New York.

Canals, *the Hennepin, and Illinois, and Michigan.* Surveys and estimates, comparison of routes, etc. Rep. of Chief of Engrs., 1883, v. II., p. 1763.

Cement Tests, *a Uniform System for.* Preliminary report by a committee with discussion. Tr. Am. Soc. Civ. Engrs., v. XIII., p. 53.

Chemical Obstructions in Iron Water Pipe, describing samples in Philadelphia, with *fac simile* lithographic plate. By Col. Wm. Ludlow. Proc. Engrs. Clb., Philadelphia, v. IV., No. 2, p. 65.

Combustion of Fuel in Furnaces by Natural and by Forced Draught. A description of a great many experiments made in England, with results and conclusions. By James Howdon. Reprinted from *Iron* in Van Nostrand, v. 3, p. 248 (Sept., 1884).

Compensation for Railroad Curve. By William R. Morley, with valuable discussion giving both theory and practice on many roads. Tr. Am. Soc. Civ. Engrs., v. XIII., p. 188.

Continuous Girder, Application of Theorem of Three Moments to Computation of. By associates of the Royal Col. of Sc. for Ireland. Analytical and graphical treatment, but no improvement on American methods. *The Engineer*, Sept. 5, 1884.

Cribs, *New Arrangement of Superstructive*, for increased cheapness and strength. Rep. Chf. of Engrs., 1883, v. II., p. 1810.

Crushing Strength of Ice, being account of elaborate experiments by the government. Col. Wm. Ludlow. Proc. Engrs. Clb., Philadelphia, v. IV., No. 2, p. 93.

Dredging *at Oakland Harbor, Cal.*, being an account of extensive operations where the material is pumped up and forced through long lines of pipe to the deposit beds. With plate. Tr. Am. Soc. Civ. Engrs., v. XIII., p. 9.

Flood Heights in Rivers, as affected by the destruction of forests. By Thos. P. Roberts, with discussion and plates. A large mass of data with important conclusions. Tr. Engrs. Soc. West. Penn., Pittsburg, 1884.

Flow of Water *through Turbines and Screw Propellers.* Paper read before British Assc. at Montreal, 1884, by Arthur Rigg, of London. Discussion based on empirical data. *The Engineer* for Sept. 12, 1884.

Foundations of the new Capitol at Albany, described by the Engineer, William Jarvis McAlpine, in a paper to the Inst. of Civil Engrs., showing in detail how he was enabled to obtain uniform unit pressure under all parts of the structure. Reprinted in Van Nostrand, vol. 31, p. 242 (Sept., 1884).

Healthy Foundations. By Glenn Brown, Arch. A series of articles elaborately treated and illustrated in *The Sanitary Engineer*, New York, vol. 10, running through many numbers.

Heating and Ventilation of School Rooms, as practiced in France. Summary of the practice adopted in accordance with plans proposed by Society of Public Medicine and Professional Hygiene. *Sanitary News*, Chicago, v. IV., p. 132.

Hydraulic Tables to facilitate computations by M. Du Buat's formula expressed in Eng. inches, giving results slightly less than Neville's Tables. Proc. Am. Water Works Assen., 1884. J. H. Decker, Secy, Hannibal, Mo.

Illuminating Power of Gas. nstruments for testing—not a photometer—full illustrations. *The Engineer*, Sept. 19, 1884.

Jetties *at the Mouth of the Mississippi River.* Surveys and examinations for 1883, with numerous charts and plates showing their effect on shoaling beyond their mouth, etc. Rep. Chf. of Engrs., U. S. A., 1883, v. I., p. 1031.

Leveling, Precise. Reports on field methods, with results, discrepancies, elevations and descriptions of bench-marks, from Biloxi, Miss., to Carrolton, La., and from Cairo, Ill., to Fulton, Ill. Rep. Miss. Riv. Commission, St. Louis, 1883, p. 48.

Mechanical Engineering: the outline of a course of instruction, with arguments by Robt. H. Thurston, Jour. Fr. Inst. v. CXVIII., p. 188 (Sept., 1884).

Mississippi River Bottoms, Geology of. Being a report on numerous borings made throughout the lower river bottoms, with important conclusions. Rep. Miss. Riv. Com., St. Louis, 1883, p. 479.

Mississippi River Improvement. Methods employed on the Miss. River below Cairo. Rep. Miss. Riv. Com., St. Louis, 1883, pp. 349-478.

Natural Gas. Report of a committee of the Engrs. Soc. of West. Penn., Pittsburgh, on its composition, utilization, illuminating and heating power, explosibility, etc., with discussion made May 21, 1884.

Pile-Driving in Sandy Soils. An elaborate report on the methods employed on the Mississippi River and elsewhere, comparisons of methods by water jet and steam hammer, with suggestions for further improvements. By Lt. F.V. Abbot. Rep. Chf. of Engrs., U. S. A., 1883, v. II., p. 1249.

Pontoon Railway Bridge across the Miss. Riv. at Prairie du Chien. Description, with plates and discussion. Tr. Am. Soc. Civ. Engrs., v. XIII., p. 67.

Portland Cement Tests. Very elaborate, both as to times allowed for setting and as to composition. Results plotted. Very valuable record. Rep. Chf. of Engrs., 1883, v. II., p. 1849.

Potomac River Flats in front of Washington, a complete history of the river's changes for 100 years, an account of all former attempts at reclamation, a history of the long bridge and its effects, together with a full account of the methods now in operation for reclaiming them. Rep. Chf. of Engrs., U. S. A., 1883. v. I., p. 770.

Railroad Earthwork. Diagrams and tables for simple and compound formations. By Edward Thiange and J. M. Rüdiger, together with graphical determination of haul. Pro. Engrs. Clb., Phil., v. IV., M. 2, pp. 67-92.

Reservoirs, *at Head Waters of the Mississippi River.* A progress report, with cross-sections of dams, estimates of cost, etc. Rep. of Chf. of Engrs., 1883, v. II., p. 1455.

River Discharge. Reports on methods and results of eight parties on the Miss. River, each for one year's observations, 1881 and 1882, together with computed daily discharges of the river at many other points for the year 1882. Rep. Miss. Riv. Com., St. Louis, 1883, p. 178.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 17, 1884:—A regular meeting of the Boston Society of Civil Engineers was held in Wesleyan Hall, at 8 P. M., Vice-President L. Frederick Rice in the chair ; twenty members and two visitors present.

The record of the last meeting was read and approved.

The Committee appointed by the President to consider the matter of Amendments to the Constitution relating to dues presented the following report :

ARTICLE XIV.

Any person duly elected shall become a member on subscribing his name to the Constitution and paying ten dollars to the Treasurer.

ARTICLE XV.

Members shall be liable for the payment of such assessments as shall be voted by the Society ; except that during residence 80 Km. or more from Boston, any member whose dues have been fully paid, and who shall give written notice to the Secretary, may thereby be exempted from any assessment levied before the next annual meeting, and, by the payment of $3 at or before the annual meeting, may retain his membership and be exempted from any assessment during the year following such annual meeting, or for any less period that his non-residence shall continue.

ARTICLE XVI.

Honorary members, having been nominated as required in Article XII., may be elected by a unanimous vote. They shall be subject to no fees or assessments. They may attend any meetings of the Society, but shall not be entitled to vote.

ARTICLE 5—BY-LAWS.

5. Ten months after an assessment is levied the Secretary shall send the following notice to any members who have not paid the same nor been exempted from payment :

DEAR SIR :

Your assessment, levied..................................not having been received, in conformity to the by-laws, your attention is hereby called to Art. XVIII. of the Constitution, which is as follows:

ARTICLE XVIII.

Any member who does not pay his assessment within eleven months after it is levied shall cease to be a member, but his debt to the Society shall not thereby be discharged.

L. FREDERICK RICE,
FREDERICK BROOKS, } Committee.
E. W. HOWE,

On motion it was voted that the report of the Committee be accepted and the Committee discharged.

On motion it was voted that the proposed articles be considered separately.

On motion it was voted that Article XIV. of the Constitution be stricken out and proposed Article XIV. be substituted.

Affirmative, twenty; negative, zero.

On motion it was voted that Article XV. of the Constitution be numbered XVI. Affirmative, nineteen; negative, zero.

On motion it was voted that proposed Article XVI. of the Constitution be stricken out and proposed Article XV. be amended by substituting 50 miles for 80 kilometers.

On motion it was voted that proposed Article XV., as amended, be adopted. Affirmative, 12; negative, 4.

On motion it was voted that Article 5 of the By-Laws be stricken out and proposed Article 5 be substituted.

On motion it was voted that the Treasurer be authorized to pay $4 of the membership fee due from H. F. Walling, who has been a member of the Society and withdrawn in good standing.

Mr. M. M. Tidd was proposed for membership, recommended by Messrs. Henry Manley and Alexis H. French.

Mr. George H. Crafts was proposed for membership, recommended by Messrs. F. P. Stearns and Seth Perkins.

Mr. Desmond Fitz Gerald addressed the Society on "Rain Gauges and Self Recording Apparatus."

Mr. Frederick Brooks read a paper on "The Theory of the Polar Planimeter," referring to a paper read at one of the early meetings of the Society.

(*Adjourned.*) H. L. Eaton, Secretary.

VISIT OF THE SOCIETY TO THE IMPROVED SEWERAGE WORKS.

On Wednesday afternoon, August 27, the Society visited the works of the Improved Sewerage in accordance with arrangements made by the Committee on Excursions.

The party, which numbered about fifty-three members and invited guests, started from Long Wharf and went first to the pumping station, where they witnessed the working of the large Leavitt and Worthington pumps and the raising of the "filth cages." The sewage was also inspected where it flows from the force mains into the tank sewers and where it enters the west shaft of the tunnel.

The next place visited was Moon Island, where the reservoir gate-houses and other works were examined and the discharge of the sewage stored since the previous tide was witnessed. From Moon Island the party returned to the city.

The trip from point to point was made on the steamer Tourist, which was placed at the disposal of the Society through the courtesy of C. W. Raymond, Major of Engineers U. S. A., member of the Society; and the day being pleasant the trip proved to be enjoyable as well as instructive.

The excursion was under the immediate direction of Mr. F. P. Stearns, to whom the Society is greatly indebted for arrangements which were made for the trip. The Society is also under great obligation to Maj. C. W. Raymond for the use of the steamer Tourist.

VISIT OF THE SOCIETY TO ECHO BRIDGE, NEWTON UPPER FALLS, SUDBURY RIVER CONDUIT AND CHESTNUT HILL RESERVOIR.

On the afternoon of September 17 some 30 members of the Society accepted the invitation of the Committee on Excursions and visited the Echo Bridge over the Charles River at Newton Upper Falls.

After examining the bridge the party was taken in boats through the Sudbury River Conduit from Newton Upper Falls to Chestnut Hill Reservoir.

At the Reservoir the party was shown the terminal chamber, the rain guages, and self-recording apparatus connected therewith.

The party was under the immediate direction of Mr. Desmond Fitz Gerald, Superintendent of the Western Division, Boston Water-Works, to whom the members were indebted for a very pleasant and instructive excursion. H. L. Eaton, Secretary.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

Ninth Report of the Committee on the Metric System of Weights and Measures.

To the Boston Society of Civil Engineers:

Bill in Congress.

Your committee, instructed March 16, 1881 to "gather from time to time and present to the Society all attainable information relative to the introduction of the metric system," has to say that in the national House of Representatives, June 30, 1884, there was introduced from the Committee on Coinage, Weights and Measures, and is now pending, a bill (of which a copy is annexed) requiring the Government Departments to use the metric system from March 4, 1889. Two things remain to be done: to pass the bill, and to carry its provisions into effect.

First, such a bill will be passed when every Congressman knows that his constituents demand it. Hence every citizen is advised to mail to his Representative, or to any other Representative with whom he may be better acquainted, addressing House of Representatives, Washington, D. C., his petition, either in the simple form appended to this report or in any other form. Under the rules such petitions are referred to the Committee on Coinage, Weights and Measures, which has charge of the bill. If the press of business should prevent the present Congress from acting on it, the next Congress can be memorialized, and as new Congresses come in every two years, they can be successively appealed to until some enactment is made.

Secondly, to get the proposed law so carried into effect as to do the most good requires an acquaintance with the metric system by the people with whom the government deals as well as by the government officers; it requires that the metric system should be generally adopted in private transactions at the same time as in governmental transactions or as rapidly as possible thereafter; it requires that between now and the date to be fixed by the enactment, the preparatory steps of the change should be deliberately and carefully made in all other classes of measuring as they have already been, or are now being made in various branches of work specified in the several reports of your committee during the past nine years.

Recent Progress.

Since its last report a few additional particulars of this gradual progress have been collected, some of little significance, some of much.

Electrical science, whose applications are now being marvelously developed, has its units, the *ohm*, *volt*, etc., founded on the metric measures. The basis for the system was furnished by a committee of the British Association for the Advancement of Science. At an international convention, which met at Paris in April, 1884, where there were nine delegates deputed by the British Government, and where the United States, Russia, Persia, China and Japan were also among the nations represented, it was agreed, after ample discussion, that the legal *ohm* is the resistance of a column of mercury one square millimeter in cross-section, and 106 centimeters in length at the temperature of melting ice. This and other units connected with the centimeter, gram and second were indorsed. The American Electrical Conference called together in Philadelphia, 8th September, 1884, for the purpose, among other things, of taking authoritative action respecting these electrical standards, favored their adoption, and deemed it of national importance that Congress should fix standards of electrical measures.

At Minneapolis flour is put up in bags of 50 kilos and 100 kilos for exportation to the continent of Europe.

The Barnes micrometer caliper, patented in 1883, for measuring wire, etc., is advertised by A. J. Wilkinson & Co., of this city, graduated either in metric measure or in decimals of an inch.

An important step preparatory to the free use of the metric system is the publication in metric measure of such reference books and tables of data as are commonly used in various professions and trades. Its gradual introduction in such places comes within almost every one's observation. In the table issued by the Iron and Steel Wire Manufacturers' Association, England, giving sizes, weights and breaking strains of iron wire according to the imperial standard wire gauge established March 1, 1884, diameters are given in millimeters as well as in inches. Metric expressions of quantity appear very frequently upon the pages of the ninth edition of the Encyclopædia Brittanica, now in course of publication, but were found scarcely anywhere in the eighth. In the forthcoming edition of Henck's Field Book for Railroad Engineers, a table of metric railway curves is for the first time inserted.

W. S. Fortescue & Co., of Philadelphia, have recently published Metrical Tables, simply arranged on a large sheet, by Olin H. Landreth, professor of engineering in Vanderbilt University, Nashville, Tenn.

In the Transactions, published by the Association of Engineering Societies, there have been up to the present time 118 papers containing expressions of weight or measure; 8 of these have used the metric system chiefly or wholly; 13 others have contained metric in addition to old denominations; the remaining 97 contained only the old weights and measures, among others the 4-rod chain with its link, the front foot, the square (of 100 square feet), the miner's inch of running water, the perch of masonry, the bushel of coal and of grain, the fluid ounce, the minim, two different tons, the troy ounce and the drachm.

The Civil Engineer's Way.

A step that the engineer has frequently taken, and can perfectly well take without waiting for his neighbors, or for legislation, is to add a metric linear scale to all the plans drawn in his office.

In land surveying not connected with previous work and not to be directly followed by construction, such surveying, for example, as is often done for determining areas of making plans and descriptions for record, metric measures may easily be used in the field. Some cases in which they have been used have been mentioned in previous reports. A new case is the surveying of some plantations near West Point, Virginia, during the present year by Mr. F. E. Montague, who had to reduce all his results to old denominations for the accommodation of the conservative landholders.

Another introductory step that engineers would do well to take is to abandon the U. S. gallon in water computations as a worthless unit. American water-meters read in cubic feet; the city of Boston measures water with them and makes out consumers' bills in cubic feet. To supply incongruity, the paper on which the city of Boston takes the diagrams of its Deacon waste water meters is ruled to read U. S. gallons and the reports of the Boston Water Board give in U. S. gallons statistics of consumption, quantities pumped, contents of reservoirs and flow of streams, which means that somebody's labor was expended in computing the figures from dimensions measured in feet and inches. The liter would be no more awkward than the U. S. gallon is in its relations to most of the other kinds of measure used for similar purposes, as is shown by the little table below giving their equivalents.

	Cu. inches.	Number in a cu. ft.	Number in a U. S. bushel.	Pounds of water.	Fraction of British gallon.	Number in a cu. meter.	Kilos of water.
U. S. gallon..........	231.	7.4805	9.3092	8.3452	.83311	264.18	3.7853
Liter....	61.025	28.316	35.238	2.2046	.22009	1000.00	1.

The "Winchester" or U. S. gallon was abandoned by Great Britain about 60 years ago. It is frequently a fictitious unit, 1 cu. ft. making 7½ nominal gallons, instead of 7.4805+ U. S. gallons, or 1½ cu. ft. per second making 1,000,000 nominal gallons per day instead of 969,475 U. S. gallons; in either of which cases the spurious unit appears to be quite superfluous; if a certain number of cu. ft. is meant, why should it not be said ?

In water analysis the old custom of stating the amount of impurities in grains per gallon is giving place to the expression in parts per 1,000 for mineral waters, and in parts per 1,000,000 or per 100,000 for potable waters; the latter has been used more commonly, but parts per 1,000,000 have the advantage of corresponding to milligrams per liter or grams per cubic meter.

Mr. Rudolph Hering, hydraulic and sanitary engineer, of Philadelphia, frequently uses the metric system in his private work to simplify calculation, translating his results when necessary into old denominations.

What is the Use ?

Discussion of the metric reform has digressed so that the chief benefits it promises are in danger of being lost sight of. Besides being a system (which our unrelated old weights and measures notoriously are not), the metric system is *decimal*, and has the same advantage as our decimal money, which was adopted by act of Congress a century ago, but which was brought into complete use by our people only after years of annoyance from conflicting coinages and reckonings, such an annoyance as inevitably accompanies the introduction of any improvement. Let us now adopt the meter, gram and liter, to complete the process of decimalization. If, excepting the temporary inconvenience and expense of a change, there is any reason why we should adhere to the yard, pound and gallon, then let us, for the same reason, return to our hereditary pounds sterling, shillings and pence, and not stultify ourselves by acting inconsistently in the two similar cases. There ought to be a correspondence between our coinage system and our weights and measures for the sake of convenience, as may be simply illustrated. If iron is worth $40 per metric ton, it is obviously worth 4 cents per kilo; but if iron is worth $40 per old ton, the price per pound must be ciphered out as $\frac{4000}{2240}$ cents. If land is worth $1,000 per hektar, it is obviously worth 10 cents per square meter ; but if land is worth

\$1,000 per acre, the price per square foot must be ciphered out as $\frac{100000}{43560}$ cents. A community engaged in commercial business will find such correspondence vastly useful. Would we see ourselves as others see us? In Sweden in 1848 Mr. Wallenberg opposed the decimalization of money without weights and measures, because a visit of three years to America had shown him how inconvenient in business is a duodecimal system of weights and measures combined with a decimal currency.

That decimal subdivision of weights and measures is destined to prevail here is a plain inference from the fact that decimals of the old units are perpetually being used, in spite of their incongruity with the old established subdivisions. Surveyors have used decimals of the acre and decimals of the furlong (the chain still used on United States public land surveys as well as in England and her colonies), and they now use decimals of the foot in measuring land and in measuring vessels for tonnage. Decimals of the inch are used by machinists, on gauging-rods for casks, to express size of wire and sheet-metal, etc., etc. Some mills use decimals of the hour and astronomers use decimals of the day, hour and minute. The British authorities provide standard small weights, which are decimals of the ounce and the grain. Yet the awkward relation of these decimals to the other recognized subdivisions is always making trouble. Much more acceptable, then, must be decimals which are themselves the standard subdivisions and which harmonize with all parts of a complete system; they are to be had by adopting the metric units. For instance, in such handy volumes as Trautwine's Civil Engineer's Pocket-Book and Shunk's Field Engineer are comprehensive tables for reducing inches and their binary subdivisions to decimals of a foot, also tables for the interconversion of gradient expressions in decimals per 100 and feet per mile. The existence of these tables testifies that such conversions are common, and that assistance is wanted to make them. These things and many others like them can be dispensed with by the adoption of the metric system; for everybody will know that centimeters are hundredths of a meter, and will no more need a table for the conversion than he now does for converting cents into decimals of a dollar; and every engineer will know that a gradient of 15 meters per kilometer is 1½ per 100, and will no more need a table to show it than he now does to show that a tax of \$15 on every \$1,000 is at the rate of 1½ per cent. So in those odd classes of measure where decimals of old units have already been thrust, greater convenience will be obtained by introducing the completely decimal system.

Moreover that will extend the benefits of decimalization to all other classes of measure and simplify their relations with one another. Instead of laboriously reckoning that if rails weigh 60 pounds per yard, a mile of track requires

$$\frac{2 \times 60 \times 1760}{2240}$$

old tons, we can see at once that if rails weigh 30 kilos per meter, twice 30 metric tons per kilometer are required for single track consisting of two lines of rails. Contrast the reports of sewage farms in England and on the continent of Europe; at one of the latter 15 liters of sewage per square meter can be applied to the land per day, and it is a convenience in calculation that this is equivalent to a depth of 15 millimeters over the surface. If at an English farm 15,000 imperial gallons per acre can be applied per day, it is not convenient to calculate the equivalent depth in inches, equal to

$$\frac{15000 \times 277.274}{43560 \times 144}$$

In pharmacy an excellent example is now set for other business to follow. Prescriptions have heretofore been written in the mysterious denominations of the old apothecaries' tables, and with the Roman numeral letters; but a change is now in progress to decimal arithmetic with the common, or Arabic, figures and the metric system of weights and measures. Here is the prescription for a mixture with quantities expressed in the customary style in column 1; column 2 gives the metric expressions of quantity to be substituted in order to convert it into a metric prescription

℞		Column 1.	Column 2. Gramma.
Quin. Sulphat		gr. xvi.	1.
Strych. Sulphat		gr. ss.	.03
Acid Hydrochlor. Dil		♏. lxxx.	5.
Tr. Zingiberis		ʒ ii.	7.50
Tr. Card. Co.		ʒ iiss.	9.50
Syrupi		℥ ii.	80.
Aquam	ad	℥ iv.	40.

M. Sig. Dose, a tablespoonful.

In a case of sickness, last summer, a lady tried to telegraph a prescription written in the customary style, but as neither she nor the telegraph operator understood the expressions of quantity, they naturally failed to communicate them correctly, though the names of the ingredients were successfully transmitted. If the metric system were in use by everybody prescriptions could easily be telegraphed. This incident is one little illustration of the really great disadvantage of weights and measures peculiar to a special class of business and unintelligible to persons outside of that business. Into the same category with the scruple and minim of the apothecary must be put the surveyor's link, the perch of masonry, the miner's inch, the jeweler's carat and the horse-jockey's hand. Other units are equally to be condemned, if not for the same reason; for instance the U. S. gallon already spoken of, the U. S. bushel of 2,150.42 cubic inches and the U. S. troy pound of 5,760 grains, all of which Great Britain has abandoned. If physicians and apothecaries are making a judicious reform, let all our people do likewise and adopt the metric system throughout. If, on the contrary, there is any sufficient reason why we should adhere to our other hereditary units, let us for the same reason urge our physicians and apothecaries to adhere to their U. S. units (abandoned by the mother country) and to their antiquated jargon.

Respectfully submitted,

CHARLES H. SWAN,
FRED. BROOKS,
CLEMENS HERSCHEL, Committee.

OCT. 15, 1884.

ENGINEERS' CLUB OF ST. LOUIS.

OCTOBER 23, 1884:—This, the first meeting after the Summer vacation, was held at Washington University. President Woodward explained the object of the meeting being called earlier than the date to which the Club had adjourned, viz., November 12. This was in order to hear a paper which had been prepared, and which was needed by way of necessary copy for the JOURNAL, and also to arrange for the work of the ensuing year.

The minutes of last meeting were read and approved.

The question was raised whether new members could be elected at this meeting. It was decided by vote to proceed to the regular order of business, and a ballot was taken on the name of Mr. J. D. Sanders. He was unanimously elected.

The following names were proposed for membership:

E. D. Libby, J. E. Savage, Gerald Bagnoll, W. S. Mitchell, by C. V. Mersereau and M. L. Holman; C. C. Brown, by J. B. Johnson and C. V. Mersereau; H. S. Pritchett, by Robt. Moore and J. B. Johnson.

Communications were presented from the Smithsonian Institute, asking for likenesses of scientific men, and one from the International Institute for Preserving and Perfecting Anglo-Saxon Weights and Measures. These communications were ordered filed.

It was moved that a committee of three be appointed on a revision of the Constitution. Robt. Moore, E. A. Engler and W. H. Bryan were appointed on this committee, and they were instructed to report at next meeting.

Moved that a committee of three be appointed on programme for the coming year, of which the President should be a member.

Robt. E. McMath and J. A. Ockerson were appointed as the other two members.

Moved that when the Club adjourn it be at the call of the President.

Mr. J. B. Johnson then read a paper on "The Creeping of Rails on the St. Louis Bridge." The discussion of this paper was postponed to the next meeting.

The Club then adjourned to an adjoining building to inspect a working model which had been prepared to illustrate the movement of rails. It was shown that when the rail rests on the bottom, and has an independent wave motion of its own, the rail moves *with* the traffic, but when hung from the top, and has this wave motion, it goes *against* the traffic.

J. B. JOHNSON, Secretary.

WESTERN SOCIETY OF ENGINEERS.

SEPTEMBER 16, 1884:—The 194th meeting was held at 4 P. M., Vice-President Wright in the chair.

The minutes of the preceding meeting were read and approved. (Minutes of

previous meeting should show that Mr. Saltar was indorsed by Mr. Randolph instead of Mr. Wright, as printed.)

The Secretary presented a communication received from the New York and New Jersey Branch of the International Institute for Preserving and Perfecting Anglo-Saxon Weights and Measures, asking the co-operation of the Society with it.

The letter and accompanying papers were referred to the Committee on Weights and Measures.

It was voted that the bound volumes of the Transactions of the Society now in the library, with the exception of five copies of each volume, be distributed, without charge, to members who have not received copies, upon their application.

The following was presented :

Resolved, That the Secretary is hereby directed to send to members whose dues are still delinquent for the first six months of 1884, the notice contemplated in Section 7 of Article VI. of the By-Laws.

Action on this was postponed till the next meeting.

The Secretary announced the receipt of a photograph-likeness from M. E. H. Beckeler.

The Secretary read a Memorial Paper, prepared by Mr. E. A. Fox, on the late Mr. Alexander Wolcott, one of the earliest members of the Society.

It was voted that this paper should be printed, and that the Secretary send a copy to the family of Mr. Wolcott.

Mr. Randolph exhibited, with explanation, the model and drawings of an interlocking switch and signal apparatus, designed by himself, and which is in use upon the Chicago & Western Indiana Railroad.

It was voted that the description given by Mr. Randolph be printed.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

IN MEMORY OF THE LATE ALEXANDER WOLCOTT, C. E.

BY E. A. FOX.

This Society has again had its ranks broken by the death of one of its oldest members ; oldest both in years and in date of membership.

Alexander Wolcott, the venerable County Surveyor of Cook County, has leveled up his transit for the last time and made his last survey.

He was born in Middletown, Conn., Oct. 9, 1814, received his mathematical education at West Point, came to Chicago in 1834, and died August 11, 1884.

The Chicago members of our Society will miss his spare, active figure and white, flowing locks, moving through our crowded streets with the active step of a young man.

Mr. Wolcott's career is almost identified with that of Chicago, as they grew up together. He commenced his business life as an engineer on the Illinois & Michigan Canal, and the Illinois Central Railroad, but soon turned his attention to land surveying, for which this rapidly growing city has always offered a tempting field, and the temptation was sufficient to keep him always at work from youth to age, a busy pioneer, marking out the lines of our noble streets, and preceding the architect and builder in fixing the location of those magnificent structures whose individual value is counted by millions, and that of the land on which they stand at hundreds of dollars per inch.

Mr. Wolcott has left no great monuments of engineering skill, no stupendous bridge, tunnel or hydraulic works to identify with his

name, but his long practice of his profession in the building of this mighty city, and still more in its rebuilding after its destruction, in all of which he took an active part to within a few months of his death, and his long incumbency of the office of County Surveyor—nearly thirty years—show that whatsoever his hand found to do he did it with his might, and to the satisfaction of his fellow citizens. His most characteristic trait was an untiring energy and activity. No task was too hard, no place too rude for him; he seemed to delight in fatigue and exposure. He was rough but kindly, a man knowing and known by all, and universally popular; a hasty temper of that well known type, "That much enforced shows but a hasty spark, and straight is cold again."

The writer in nearly ten years' business partnership with the subject of this memorial can say that no serious difference ever rose between us, that we parted in 1875 on the most friendly terms, and maintained the most amicable relations till the last great parting, when having almost exactly filled the three score and ten years allotted to mankind, he left us, and we may say emphatically, that he well filled the measure of his long and busy life as a man, an engineer, a worthy citizen and a friend.

OCTOBER 7, 1884:—The 195th meeting was held at 4 P. M., President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Upon ballot, Mr. John Saltar, Jr., was elected a Member.

Mr. Liljencrantz, for the Committee on Revision, submitted a report embodying several amendments to the Constitution and By-Laws.

The amendments proposed by the Committee to Articles IV. and V. of the Constitution were seconded by the requisite two-thirds vote.

The amendments proposed by the Committee, as amended, to Articles IV. and V. of the By-Laws were received, and it was voted that a letter ballot should be taken on the proposed amendments to the Constitution and By-Laws at the second meeting in November.

Mr. Williams, Manager for this Society in the Association of Engineering Societies, presented a bill of $134 from the Association, which was ordered paid.

The following was adopted:

Resolved, That members are hereby requested to send to the Secretary, on or before December 2, written nominations for the officers to be elected at the annual meeting January 6, that the nominations so received be read at the meeting December 2, and that the two names receiving the largest number of proposers shall be declared the nominees for the respective offices.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

OCTOBER 21, 1884:—The 196th meeting was held at 4 P. M., Vice-President Wright in the chair.

The minutes of the preceding meeting were read and approved.

The Secretary read a letter from the St. Louis Engineers' Club urging this Society to remain a member of the Association of Engineering Societies.

The Secretary also read a letter, addressed to the President, from Mr. J. F. Holloway, President of the Civil Engineers' Club of Cleveland, requesting the Society to reconsider its action of withdrawal from the Association, and inclosing a series of resolutions to the same effect adopted by the Club.

It was voted that these communications be received and placed on file.

After discussion of the subject matter of these communications the following preamble and resolutions were adopted:

Whereas, Since the vote to withdraw from the Association of Engineering Societies it

is believed that many members who then favored withdrawal have changed their views ; and

Whereas, The other participating societies have urgently requested us to retain our membership ;

Resolved, That members are hereby requested to present written opinions on the question of remaining a member of the Association, and that at some meeting not earlier than December 2, a vote be taken on the question.

The paper by Mr. Wright on "Street Railway Joints," published in the JOURNAL for September, was taken up for discussion, after which the meeting adjourned.

L. P. MOREHOUSE, Secretary.

Appendix to the Ninth Report of the Committee on the Metric System of Weights and Measures.

To the Hon. the Senate and House of Representatives of the United States in Congress assembled:

The undersigned prays your honorable body to enact the bill (H. R. 7492, 48th Congress, 1st Session) which was introduced June 30, 1884, by Mr. Everhart, as follows:

A BILL

To establish the metric system of weights and measures in the Departments of the Government.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:

That from and after the fourth day of March, anno Domini eighteen hundred and eighty-nine, the metric system of weights and measures, as recognized and expressed in section thirty-five hundred and seventy of the Revised Statutes, shall be exclusively employed by the several Departments and branches of the Federal Government in the affairs of the United States: Provided, that in all other transactions than those in which the United States is a party it shall be lawful to employ the weights and measures now in use.

Sec. 2. That a knowledge of the said metric weights and measures shall be taught in all the schools and colleges now under the control of the Federal Government or hereafter aided by it, or such knowledge shall be required for admission to the said schools and colleges.

Sec. 3. That all laws inconsistent herewith are hereby repealed.

BOSTON SOCIETY OF CIVIL ENGINEERS

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. IV. December, 1884. No. 2.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

IMPROVED SIGNAL APPARATUS USED ON THE BOSTON & ALBANY RAILROAD.

BY GEORGE R. HARDY, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read October 15, 1884.]

I wish to call your attention to the method of using local signals on the B. & A. R. R.

On the single track lines with simply the No. 1 track and passing points or sidings, trains may have rights in either direction as per time cards or instructions. On the double track parts, track No. 1 is for trains going from Boston and track No. 2 is for trains going toward Boston. On the four-track portion, tracks No. 1 and 3 are for the outward and tracks 2 and 4—even numbered—are for inward trains, thus making two parallel double track lines side by side.

A railroad is never finished. Sidings are increased, single tracks must be doubled, and double tracks spread apart for the middle turnouts to be finally succeeded by the four-track system with enlarged terminals and more switching tracks.

The four-track portion of the B. & A. extends from Tower No. 6 at Huntington avenue, Boston, to Tower No. 15, at Riverside, where the increased facilities and junction form a lay-out which is equipped in as complete and progressive a style as any in this vicinity.

Tracks 1 and 2 are used by trains not stopping at stations, such as express, passenger and freight trains, as there are no stations or platforms for passengers for those two tracks on the four-track portion.

Tracks 3 and 4 are used by all the passenger trains doing local work, and some irregular trains.

At Tower 6, interlocking controls the switches and signals for uniting the four-track system on the westerly with two tracks going easterly to near the Boston depot.

At the Boston Depot, Tower No. 1 contains the interlocking for con

trolling the switches and signals belonging to the diverging tracks in and about the train-house.

Tracks 3 and 4 disappear at Tower 6, but are numbered again at the train-house.

At the train house Nos. 1, 3, 5, 7 and 9 are loading tracks, Nos. 2 and 4 are used generally as inward tracks. Odd numbers are used to designate tracks generally used for outward trains and for side or yard tracks on the right hand side of the road looking west, while even numbers are applied to tracks on the opposite side and for inward main tracks. Facing point cross-over roads have odd numbers and trailing point cross-overs have even numbers.

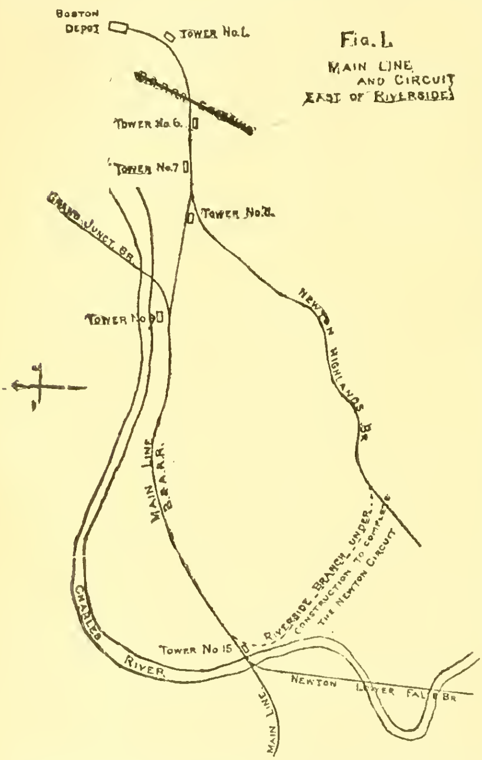


Fig. 1.
Main Line and Circuit East of Riverside.

Six depot tracks, a baggage room track, and engine track, with also two main cross-overs and two loops, and one yard-spur switch are included in the territory covered by the interlocking at Tower No. 1, arranged so that trains can be ordered in either direction between each of the eight terminal tracks and the two mains at Albany street.

From Albany street, near Tower 1, to Tower 6, the company's location is only wide enough for four tracks continuously, but instead of occupying it by four mains, it is found much better to use only the two middle tracks, as tracks 1 and 2, and save the outside room for switching.

The value of this arrangement is more apparent when it is remembered that between the two points just mentioned all trains are practically of the same class as regards speed on account of the stops at the Boston & Providence Railroad crossing, so that with a liberal arrangement of signals, by which trains can close up to quarter-mile blocks, as large a traffic can be transferred as is necessary.

Tower 7, about half a mile west of Tower 6, controls a full set of four cross over roads from track No. 1 to a yard on the south side.

About half a mile west of Tower 7 in Tower No. 8, similar to Tower 6, is an apparatus controlling the double-track branch from 3 and 4 to Brookline and Newton Highlands.

The extension of this Newton Highlands & Brookline Branch to a new

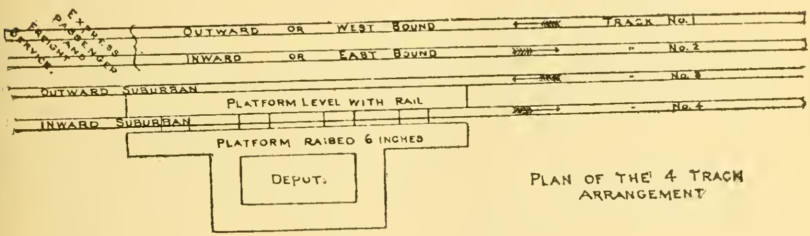
connection with the main line at tower No. 15, Riverside, will complete what is known as the Newton Circuit. About a mile west of Tower No. 8 is Tower No. 9, with two cross-overs connecting tracks 1 and 2 with the Grand Junction Branch and Freight yard. This is the route for exchange with the north side railroads, and for the ocean terminal at East Boston.

A large freight yard is one of the features at this point, extending westerly on the bank of the Charles River, and uniting again with track No. 1 by trailing point switches, worked by ground interlocking. The main tracks above described are laid with 72 lb. steel, 4½ inches high and 4½ base.

This form of rail was adopted about four years ago, and is used with double-angle joint.

The joints are laid alternately, *i. e.*, opposite the middle of the companion rail. There is a spike hole in each plate and the outside of the opposite rail is slotted for a spike on the same tie, to obstruct creeping.

FIG. 2.



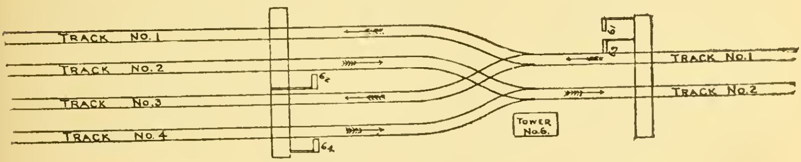


FIG. 3.

TOWER No. 6.
EAST END 4 TRACK SYSTEM.
(SAME AS TOWER No 8)

Two other quarter distant points on each rail are slotted for the same object.

Newly laid ties are 8 feet long, and lined on the right-hand side as the traffic runs. Ties are about two feet on centres, but if the rails balance truly, then there will be 16 to a 30-foot rail.

Gravel ballast is used with the surface finished as shown by the standard cross-section. Curves are elevated by the rule that gives an elevation at the T. P., as well as in the middle of the curve, viz.: Elevation = the middle ordinate of a chord X feet in length, where $X = 1\frac{1}{2}$ times the maximum speed of trains in miles per hour.

On curves of more than 2° the approaches are adjusted by the cubic parabola.

All switches and frogs used with the 72-lb. rail are made from the rails. Switches 15 feet long, frogs 12 feet, generally No. 8 stiff pattern fastened with castings and bolts.

With this rail we have point switches and rail frogs, both efficient and economical.

In past years, with rude construction of the point, rail, split, or Lorenz switches, as they are variously called, the effort to introduce them proved unsatisfactory and even rail frogs were only partially applied. Applications of interlocking have but little relations to them ordinarily, but more success is attained with point switches interlocking than with any other common forms, on account of their lighter weight.

Indeed, the Tyler switch seems only a short step in advance of what the early English builders called contractor's points, and with 1,400 to 1,700 lbs. of castings presented a heavy bill of original outlay, which can only be accounted for by considering that in this country mechanical enterprise, which ought to have introduced the necessary planers, was several years behind the demand.

The often-repeated notion that point switches are inimical to our climate on account of snow and ice have been, we think, effectually disproved, and to-day the main line of the B. & A. is equipped with point switches, two points alone excepted. The point switches are now made so as to be more easily handled than any other common form, and are undoubtedly the best for interlocking. The use of point switches introduces two new terms in the railroad vocabulary, viz., facing points and trailing points. You will instantly see that the first refers to the direction of a service by which a switch opens up a choice of two routes, and a switch trailing is one by which two nearly parallel directions of service join in one track.

With split switches, the element of safety in a trailing point is similar to that sought for, yet sometimes failing, in the use of the Tyler, while with the split switches it cannot fail if the track is complete. This is the only element of safety yet considered in the Legislations about safety switches.

With facing switches—the old apparatus was subject, 1st, to the danger of a broken switch-rod or lost motion in the connections by which a switch-rail might shift far enough to allow the wheel-flange to collide with the rail end switch and derail the car or, 2d, to slip under a train and divide the course of part of the wheels on one track and part on another.

This last, or 2d case, is almost the only danger attending the use of point switches, and has to be obviated by special arrangements. A good interlocking application always contemplates the use of the locking bolt and detector bar for all switches subject to a considerable facing point service. With the stock rails firmly held to the ties, a bolt is arranged to enter a closely fitting hole accurately placed in the rod which connects the two point rails, which bolt is so connected with the detector bar that it can be neither drawn nor thrown without swinging the detector bar, which bar, placed against the rail and of a length equal to the largest space between any two axles in a train, cannot be moved while a wheel is within that distance in front of the switch, thus obstructing the changing of the switch. Thus the switch is firmly held in its place until the train passes.

With interlocking the operator at perhaps a distant point, selected as the most advantageous place to survey the movement of trains in his territory, has control of switches, switch-locks and signals by means of

positive connections from his machine to the most distant parts of his apparatus, but his power is limited to the legitimate use of the plant, by the machine in the tower. The Saxby & Farmer machine does this mechanically. Similar levers each have connections with a switch, a lock or a signal. These levers are connected with one another so that only the proper levers can be used.

With the signals at danger, 1st, a switch can be changed, then, 2d, locked, then, last, the lever which gives the proper signal can be pulled. To return the switch the signal must, 1st, be put to danger, then the switch unlocked and then thrown, relocked, and another signal may be given corresponding to the changed route. All this is done by the lever in the tower.

This is interlocking in the brief.

I propose now to try to indicate to you some of the complications of this system which at this time may seem to you to be a very easily com-

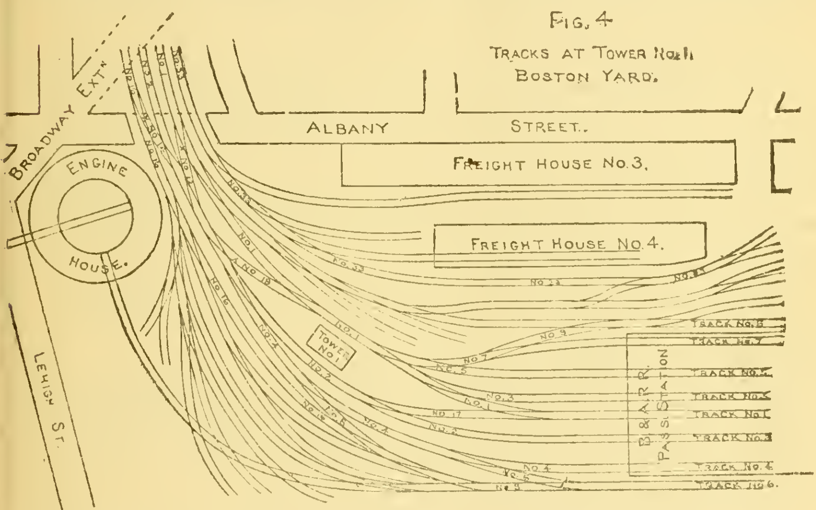


FIG. 4
TRACKS AT TOWER No. 1
BOSTON YARD.

prehended matter. I will say that I do not mean by complications any thing at all of that detail of machine work which you have seen and, perhaps, admired. That machine is simply a mechanism and its construction is a science belonging to a class of mechanics who well understand their business as well as a watch-maker or a locomotive builder, and is not a part of the work of a signal engineer by necessity.

Other makers' machines may be used with no change in the general engineering of signals.

Only this, that every signal engineer should know how to make a thorough examination of an interlocking apparatus, and such examination should always be made before the plant is put into service, as cases of faulty locking have been known to be overlooked; but they can be discovered by a systematic examination.

One peculiarity of interlocking is the fact that by its use a large economy can be made in the outlay for tracks.

While it is difficult to illustrate this fact by any general argument, yet a careful study of well signaled track plans is very convincing.

One fact leading to this economy is that while without signals an ordinarily large service at some junction point may require an exclusive track for each direction, yet with the proper signals, etc., the same work may be as well done by running one single track in either direction as the trains may arrive and with the largest percentage of safety. In three cases at tower 15, this occurs, viz. (see figure): the short part of track 3, or from the switch into track 4, to the gravel pit track, takes all the local passenger and gravel train service in each direction. Also from the gravel pit switch to the switch out of track No. 2, into track No. 3, all local passenger service in each direction. Also, still more so, on track No. 2, from the switch into track No. 3, westward to the west side of the Charles River bridge, track No. 2 carries all the inward service except the gravel trains and all the outward local service.

Interlocking machines were not the invention of one intellect nor the production of a day or a month, but are the result of years of development. The early efforts were trials to enable one person to do the work of moving the switches from a short distance where other work was so pressing as to make it desirable that no time should be wasted in footing back and forward.

Immediately a necessity appeared that some clear sign should be used to enable the engineman to know that he might safely proceed. This led to establishing a mechanical relation between the signal and the switch. Ordinary switch targets illustrate this stage.

But switch targets are connected with the switch and while they indicate the position, they do not show which way the switchman will let trains pass, and a hand or flag sign does that.

This use of the hand or flag still leaves the service dependent upon the range of accuracy that the man may possess. A next step was to so arrange his signal that while moving the switch all signals should be at danger and even after completing the switch movement, he could only pull one of the two conflicting routes.

This you will notice gives rise to the question of where should the signal be located. The result is that one of the very few axioms in signaling is to locate the signal—which may be approached until the pilot is opposite, but not one inch past it—so that it may be as near as practicable to the fouling point of the next route in conflict with it.

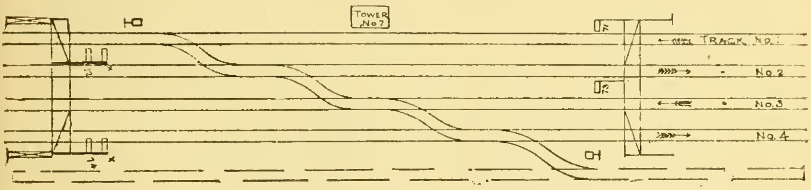
This practice differs so radically from the old style of flag and ball signaling where the custom is to stop as far away as the judgment of the engineman thinks will clear some switching movement, that it constitutes a vital change. But it has much in it that hardly appears at first. One of the features of ball signals is that they must be seen from a distance in order to guard a danger—sometimes and very generally, the entire absence of a ball indicates a right of way for speed trains, and the negative knowledge of not seeing a fog covered signal is dangerously related to the positive conclusion that the signal is not presented. Hence an important stand was made by signal engineers in favor of conducting all the service under a system of positive signals, these positive signals to bound the limits of approach and to be of

such a character that no competent man could fail to take the safe course. Thus these signals are a guard around the district controlled by the operator.

A train may only approach a signal as it can stop clear of it with; and the absolute knowledge that one is clear may pass it and proceed to the next. The signal should be located in good range of view for the engineman.

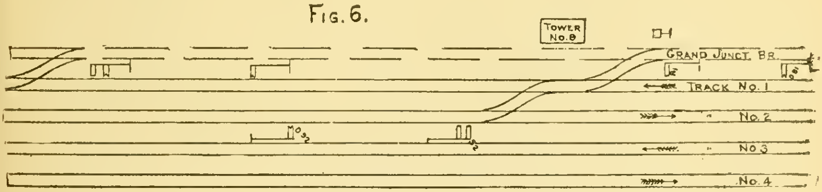
The best form used is the semaphore. Its meaning is understood at a glance—horizontally a danger signal as a man extends his arm over the track; dropping the arm, the train may proceed. Naturally with large yards and layouts and many trains awaiting to proceed, with positive signals controlled by one man, the system has advanced in practice to establish a sort of management in the hands of the operators, and under their control, subject to the general rules of the service, the work is done, and instead of a signal meaning only a permit to proceed it becomes posi-

Fig. 5.



Tracks at Tower No. 7.

Fig. 6.



Tracks at Tower No. 9.

tive and as peremptory as the immediate conditions will admit. So that the towerman, having possession of a knowledge of all the movements that are to be made, directs them to be performed at such times as he finds most serviceable.

A careful study of the plan for arranging the tracks and signals for interlocking may be found to be a source of great economy.

With the track work well planned, it is often found to be an element of safety to so interlock the switches that they may be used or opened only in the regular succession and put back in reverse order. Also notice that a cross-track becomes a unit by itself, both switches being actuated by the same lever. This, you will see, leads to an arrangement preventing an uncontrolled train on a side track from running out on the main, and taking advantage of this effectual lockout of other trains, sidings that otherwise would close in to the main track with only one switch are provided with a second switch and more rail, thereby connecting the main by a

cross-over and leaving the side track open so as to derail an uncontrolled train.

Thus substituting the danger of one evil for a larger one, in much the same way that vaccination protects from small-pox, the siding is vaccinated and a train derailed so that it may not chance to run out on the main and find an opportunity for collision.

This scheme of the throw-off on the siding has been applied to a throw-off on the main line at important points such as drawbridges and R. R. grade crossings.

I cannot help feeling that in my judgment common sense has come to a severe strain by the tendency of some advocates of this form of safe-guard to vaccinate us with a cure that is worse than the disease.

There is often more danger and more accident with the throw-off points than without, and the fact that an occasional derailment may occur on a throw-off is not sufficient argument to convince me that had the train kept the main line it must of necessity have at the same time found some other train or obstruction which would have given more serious results.

Accidents and experience on record on some of the best managed lines have been such as to throw large evidence against the policy of derailing a train in the vicinity of other tracks and trains. At a draw-bridge there seems to be no doubt that it is better to derail the train on the ground than to do the same thing in the water. In either case there must be a throw-off. Wet or dry, I prefer the dry one.

Every interlocking should supply all the signals required for every necessary movement.

Ground signals and switch indicators assist to make the system complete. When this is done so that no flagging need be done from the tower a remaining possibility of error is eliminated.

A great source of danger at an interlocking is the sometimes necessary make-shift of flagging on account of absence of interlocked signals for certain movements in switching, etc., or of repairs in progress. With this plant fly switching is not generally used, but applications have been made providing for it in a complete manner, as at the Grand Central depot in New York city.

The signal that limits the movements on the main tracks is called the home signal and at danger means a positive stop. In order to assist speed trains at that locality, distant signals are used placed at a sufficient distance outside the home signals and each dependent upon its corresponding home signal so that it cannot be pulled until the home signal is all clear, thus enabling the engineman of an express train to know by the all clear position of the distant signal that the home signal is also all clear and that he can keep up his speed.

The distant signal, usually cut with a dovetail end, when horizontal is a caution—not a full stop signal—and permits a train to pass it proceeding only as the way is known to be clear.

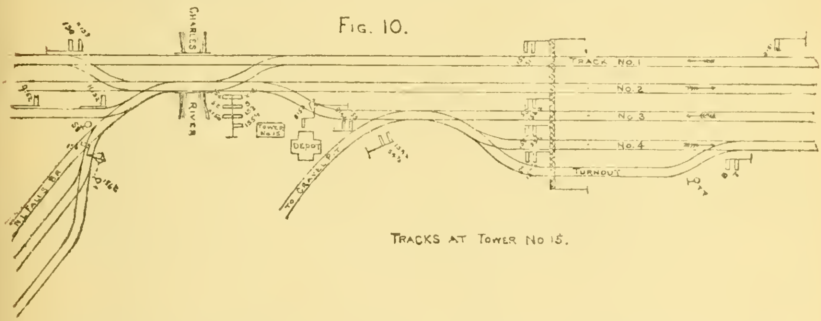
Additional safety is acquired by the use of electric locking in connection with the distant signal. This is to prevent a danger that the operator might let a train pass a distant all-clear signal and then by rapid work throw it up behind the train and next the home signal at which

the train now approaching so fast could not stop, and then unlock and shift a switch which would turn the train so that an accident might be occasioned.

Our applications of electric locking at tower 15 are so arranged that when a distant signal has been pulled all clear and the train approaching it enters upon a section of insulated track near the signal, the electric lock in the tower is applied to the levers of the locking bolts that belong to the facing point switches so that although the distant signal may be thrown up as soon as the train passes it, any change of the position of the switches is very effectual'y obstructed until after the train has passed out of said section of insulated track which extends quite past and includes all switches.

In England where the interlocking system is so generally applied under the direction or approval of the Board of Trade, the close succession of stations and towers along the lines of heavy traffic serve to divide the road into block sections of reasoable lengh, and an operator in charge of a tower is found at nearly every block section. When such sections would otherwise be too long for uniformity an extra block man is located. These men with various styles of electric and electro-mechanical com-

FIG. 10.



TRACKS AT TOWER No 15.

munications make a system of block signalling in which the semaphore signal is used. Some systems, such as the Sykes, are arranged so as to require the joint action of two blockmen to let a train enter a section, and the further advice from the second man that the train has passed him before a second train can get a signal to follow at the first block.

You will see that the conditions of such compact service are such that the additional expense of using as blockmen, men who may be tower operators generally with only a few extra men to complete the spacing of the sections, is not a large addition to train expense, and with the positive check system such as is often introduced there, the assurance of safety is very complete ; perhaps the largest element of danger may be that a part of a train can be left in the section and escape the notice of the block men. But in this country there appears to be a wide divergence of conditions as compared with England.

Here we have the longer lines, with more remote stations and junction points, also a large development of the automatic system of block signalling whereby the labor of one employé only is required to keep in service a number of blocking points ranging from ten to twenty. Even this

arrangement is often a heavy addition to the operating expenses and requires care and judgment in its location and the way it is applied.

Two classes of applications of this kind are found. One class uses detached points, such as track instruments, for setting or releasing the signals, leaving often a long space between.

The second class is that arrangement by which a section of the track is insulated and by means of electric circuits broken or maintained by the train itself the signals are operated. This commends itself in one particular especially, which is that while even a single pair of detached wheels may be left in the section, the danger signal is maintained.

While in England or at the semaphores mechanically controlled by a towerman in this country a positive iron-clad rule can be established that no train can pass without the consent of the signalman, a similar rule laid down for the automatic system would, in case of any accident to the wires or apparatus, effectually block the railroad.

Hence it has been found only practicable to establish the following for electric signals:

Rule No. 1.—When an approaching train finds a signal at danger, that is, showing a red target or light, or if the signal fails to operate, the train must be stopped and proceed only as the way is known to be clear.

This you will see is not an absolute but is a permissive block rule, so arranged as to keep the service from too serious a disarrangement, as would occur if the train was absolutely prevented from finding its way through the section.

When two trains enter a section of the class working by track instruments, under this rule, the first train, in passing out, leaves an all clear signal behind the second train, thereby inviting the approach of a third train at speed into the section, and collisions have been occasioned. With an arrangement of the second class this does not happen, because the second train holds the signal at danger as surely as the first train may.

Automatic signals on the B. & A. R. R. show red disks and are lighted with red for danger. Otherwise it is held as an axiom to avoid using the color red except in case of emergency, so that the familiar use of red may not develop indifference to its value as a signal of some unusual danger.

Electric or automatic signals are independent of the interlocking in the way they operate. They are arranged between Boston and tower 15 as overlapping blocks of the track circuit system, so that until a train has cleared the overlap distance beyond a second signal the two signals may be protecting it.

Compact succession of signals favors the movement of more trains in the same direction of that track. From tower 1 to tower 6 signals are arranged for trains to follow once in a quarter of a mile on the double track line.

Beyond tower 6, to near tower 9, with four tracks, trains may follow within half a mile, and from there to tower 15 mile blocks are used as a general plan, but interspersed with some shorter or half-mile sections on account of some necessary locations of switches.

When at a tower one route diverges into two routes, one automatic signal before reaching the switch indicates the occupancy of either of the

two routes according to the position of the switch from the section preceding to the section following.

Also complete arrangement demands that on either of two diverging routes, as soon as a train passes the interlocking, an automatic signal is required for the assurance of the track occupation, which might have been obstructed unknown to the towerman.

GEARING.

By John Walker, Member of the Civil Engineers' Club of Cleveland.

[Read October 9th, 1883.]

There is an old saying, "Expose your ignorance if you would be wise." Should this be my misfortune, or possible fortune, to-night, the writer will feel the assurance, at least, that he has done his best, and will simply be content to tell something of what he knows about gearing.

Gearing, according to Walker and Webster, is a train of wheels in machinery. There are many kinds of gears, each designed for their particular conditions and duties. They may be classified as follows :

Spur gearing is that class whose teeth are parallel to their axes, by which we transmit power from one shaft to another, whose axial lines are parallel to each other.

Bevel gears are that class whose teeth are set at various degrees from their radii, the shafts being at right angles to each other.

Angle gears are that class whose teeth, like bevel gears, are set at various degrees from their radii, but their axes are set at any angle, either acute or obtuse, or, in other words, at any angle different from 90 degrees.

Miter gears are that class whose teeth are set at an angle of 45 degrees from their radii, the shafts always being at right angles.

Hunting-tooth gears are usually classed with miter gears. The odd tooth introduced into this class of gears, to interchange the tooth positions, does not usually make enough difference to classify them as bevel gears, although in the strict sense they are bevel gears.

Internal gears are that class whose teeth, like spur gears, are parallel to their axes, but are convergent to their centers, that they may receive pinions inside their circumferences.

A rack is a series of teeth on a continuous straight line. It can be considered a spur gear of infinite radius.

Spiral gears are that class whose teeth, or perhaps more properly speaking, threads, are cut or chased at any desired angle to suit the required angle of the shafts and the required speed. The shafts of this class of gearing, however, cannot be on the same plane, their difference being that of the radii of both spirals, or worm and wheel as they are termed, when one is larger in diameter than the other.

The proportional radius of a gear or pinion is the distance from the centre to the proportional circle or pitch line, and (the pitch being the same) is proportional to the number of its teeth.

Pitch lines are the touching circumferences of two or more gears which are to act on each other.

Pitch of a gear is the distance between the centres of two contiguous teeth, measured upon their pitch line.

Line of centres is a line drawn from the centre of one gear to the centre of another, when their circumferences touch each other.

Face of a tooth is the curved part of a tooth, from pitch line to point which receives impulse on entering and imparts impulse when leaving.

Flank of a tooth is that part of tooth, from pitch line to root, which imparts impulse on entering and receives impulse when leaving.

Length of a tooth is the distance from the root or base to the extremity or point of tooth.

Breadth of a tooth is the measure of a tooth which, in a spur gear, is parallel to its axis and at right angles to its radius.

When two gears act upon each other, the greater is called the wheel and the lesser the pinion. Where the teeth of gears are of the same piece with the body of the gear, they are properly called teeth; when they are each of a separate piece they are called cogs, but are comprehended under the general term teeth.

The durability of the teeth of gears, under the same circumstances, is nearly in a direct proportion to their breadth and inversely as the pressure. The strength of the teeth of gears is directly in proportion to their breadth, as the square of their thickness, and inversely as their length. For example, if we double the breadth we only double the strength, but if we double the thickness, or, in other words, double the pitch, keeping the original length and breadth, we increase the strength four times, but as the length of teeth commonly increases with the pitch, this circumstance must be taken into view, for if we double the thickness and length at the same time (as is common in practice), we only double the strength, in which case the strength is directly as the pitch.

The stress on the teeth of gears is as the pressure and inversely as the velocity. For example, if the pitch lines of one pair of wheels move at the rate of 1,000 feet per minute, and another pair of gears, in every other respect under the same circumstances, moves at the rate of 500 feet per minute, the stress on the latter is double that on the former.

The speeds of gearing must, of necessity, vary greatly, this depending entirely on the nature of the work the gears are intended for.

The friction of teeth in gearing, as they approach the line of centres, is much greater than in receding from it. This action is more perceptible when a machine becomes worn; it causes irregularity in its movements, in consequence of the action in approaching the line of centres, tending to spread the axes of the wheels, (this will be spoken of more fully hereafter), while the action in receding from the line tends to draw their axes together, and consequently occasions additional irregular action, friction, and wear in the machine. The teeth ought, if possible, to have clearance in entering, that they may come to a gradual bearing. This is especially advantageous in cast gears. In all cases where it is admissible, the number of teeth in a pinion should be such as not to divide into the number of teeth in the wheel.

Having thus described some of the primary definitions and principles in gearing, those not conversant with this subject will be better able to understand the system about to be explained.

What is so noisy and annoying as ill-constructed gearing? Go where we may, in almost every manufactory, mill, or shop, we will find more or less irregularity in this particular branch of work. Here a pair of gears are at work, writhing and grinding in agony, ever and anon threatening to tear themselves asunder.

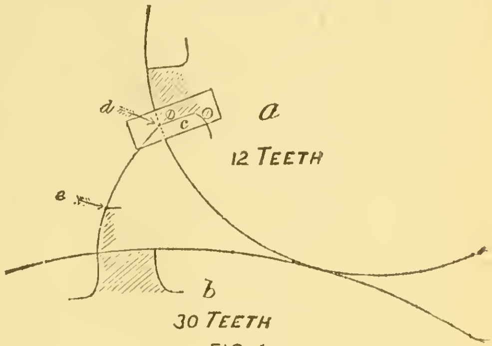


FIG. 1.

Go into the pattern rooms of many of our workshops, and you will find the secret of noisy gearing—distorted teeth of every conceivable shape and form, the majority being made by rule of random, and others fitted to them as a change of speed may have been required, albeit the fault is not, at all times, with the makers of gearing, for very often the purposes and intentions of the maker are frustrated by either flimsy foundations, shafting out of line or level, or gears not geared to their proper depth.

A story was told, some time ago, of a man receiving a mortise wheel uncogged (not having been specific in his order as to cogs) and a pinion for the same. He geared the pinion teeth into the mortises of the wheel, and then complained of their not running well and making a great deal of noise. It seems, from experience, that to have successful gearing, it is necessary for those who use it to care for it as much as the maker ought to care for its proper construction.

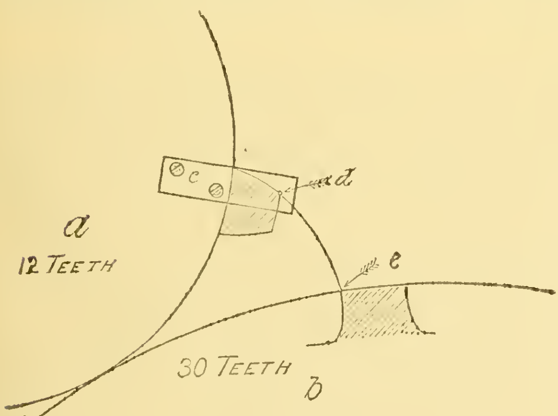


FIG. 2.

The construction or forming of teeth, in gearing of various kinds and for various purposes, is necessarily an extensive subject. I do not propose to go into details, or the fundamental principles involved in gearing in general, but more particularly to explain a new and useful system of gearing, which is the result of much research and careful practical application. Thousands of gears have been determined by this system, in this country and in England, and many flattering testimonials have been received of their easy and almost noiseless working.

The curves, from which this system was determined, are known as the epicycloid, for the faces of teeth, and epitrochoid, for the flanks of teeth. Figures 1 and 2 will serve to explain the method of generating the curves. No adopted rolling circles are used. The pitch circles generate for themselves in this system, as they do in all gears in actual service. In figures 1 and 2, two templets, *a* and *b*, are provided, representing gears with pitch diameters respectively of 12 and 30 teeth, six-inch pitch. A piece of wood, *c*, is attached to templet *a*, in Figure 1, to carry a marker *d*, to generate face of tooth for gear of 30 teeth; the marker *d* representing side of tooth, of 12 tooth pinion, will generate a face for gear of 30 teeth that will precisely contour with flank of 12 tooth pinion, when said flank is generated with a marker placed at *e*. In Figure 2 the piece of wood c is attached to templet *a*, to support marker *d* outside of pitch circle.

The position of marker represents end of tooth, and will generate flank for a gear of 30 teeth, that will contour with face of pinion tooth when said face is generated with a marker placed at *e*. By this method of generating, any pair of gears intended to work together will work abso-

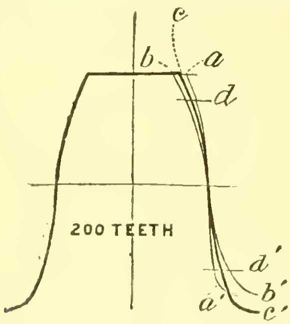


FIG. 3.

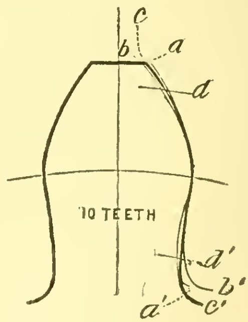


FIG. 4.

lutely correct, with true velocity ratio, and, if necessary, without any clearance at sides or base of teeth. Gears thus generated only work in pairs. In practice, the objection to this is that gears so determined will not interchange. The system we have before us overcomes this difficulty in a very simple manner, and at the same time gives as near an approximation as possible to the true curvature, as generated by pitch circles already explained.

Suppose, as in Figure 3, that the pitch circle is for 200 teeth, six-inch pitch, the curve *a a'* is generated, as already described, by using a generating circle equal in diameter to 200 teeth, six-inch pitch. The curve *b b'* is generated, as already described, by using a generating circle equal in diameter to 10 teeth, six-inch pitch. These lines, *a a'* and *b b'*, are the two extreme forms of teeth for a gear of 200 teeth, six-inch pitch, assuming 200 to be the highest and 10 the lowest number of teeth to be used for general purposes. The line *c c'* is a medium or average line of the two extremes, which is found by using nearest radii to the curves. Accepting the distance from pitch line to intersecting lines *d d'*, as that portion of the tooth that is most in contact, it is necessary

to accept this intersecting point, where the average can be taken, on account of having to allow clearance at bottom of tooth. It will be understood that the average line $c c'$ extends beyond $d d'$. It is impracticable, however, to average that portion of flank below d', on account of having to give clearance at base of teeth. That portion of face above d is caused to be slightly smaller than the average. This is a practical advantage, as it allows that part of face of tooth above d to get within the pitch circle of the opposite gear before coming in contact. This is necessary in cast gearing on account of inaccuracy of pitch in patterns, or straining of teeth in molds during casting.

Fig. 4 is a similar illustration to Fig. 3, and the forgoing explanation is adapted to both illustrations, save that the pitch circle is for 10 teeth, six-inch pitch, the curve $a\ a'$ being generated with pitch circles of 200 teeth, six-inch pitch, and curve $b\ b'$ with generating pitch circle of 10 teeth, six-inch pitch. It must be understood that whatever number of teeth the gear may contain, the 200 teeth and 10 teeth generating pitch circles must always be used. The average being taken, in all cases, the gears will interchange without deviating materially from the true epicycloidal curves of face, and epitrochoidal curve for flanks, or true curva-

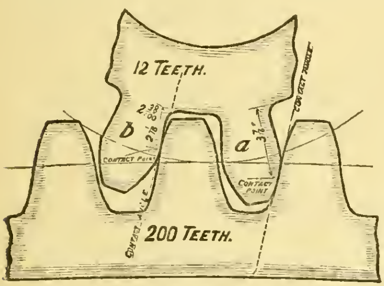


FIG. 5.

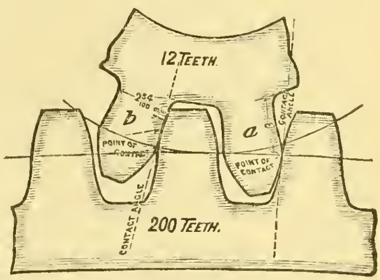


FIG. 6.

ture, as generated with pitch circles only, of which this is the nearest practical approximation.

Those who are conversant with this subject will see at once a material difference between the system here explained and that known as the Willis, or odontograph, he adopting a single generating circle the diameter of which is equal to the radius of the smallest gear in the set. Why such a generating circle is used on a pair of gears of 200 teeth, intended to work together I am at a loss to know, when the true form can only be generated by the two pitch circles being rolled together. I presume, by the above, that the 200 is prepared to work with 10 ; but the 200 is not prepared to work with one of its own size, or any other but the 10. By the Willis system we have a wedge-shaped tooth for all gears, which has a strong appearance ; but in practice this amounts to nothing, for they have less teeth in contact than those of a true epicycloidal and epitrochoidal form generated by pitch circle, which, although smaller at the root, has more teeth in contact, distributing the strain over a larger portion of the rim. At the same time there is not the objection in working out of gear as in the Willis, which is caused by the thrust from the

wedge form of tooth, wearing the bearings. It is evident that the thrust is as the incline of the surfaces of the teeth, or the contact angles to the line centres of both shafts. In pinions the Willis system has the reverse, viz., a very weak tooth at the root. Pinions ought to be as strong as

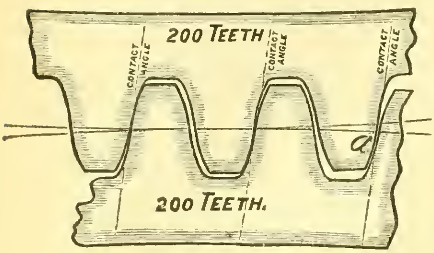


FIG. 7.

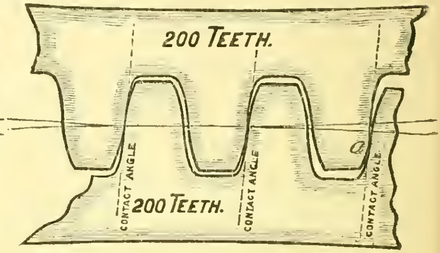


FIG. 8.

possible (without injury to their form), on account of having but one o two teeth in contact.

Figures 5, 6, 7 and 8 are drawings made to compare the Willis system with the Walker system; figures 5 and 6, representing a pinion of 12 teeth with a wheel of 200 teeth, both being drawn at the same relative position to each other, that a fair comparison may be seen of the forms of teeth and their points of contact.

In the Willis system the points of contact will be seen to be much farther from the base of the pinion tooth than in the Walker system. In the tooth *a*, Fig. 5, we have for Willis $3\frac{7}{16}$ inches as against 3 inches in tooth *a*, Fig. 6, in the Walker. In the tooth *b*, Fig. 5, we have $2\frac{1}{16}$ inches in the Willis as against $1\frac{9}{16}$ inches in tooth *b*, Fig. 6, in the Walker. The thickness of pinion tooth at base in the Willis, is $2\frac{38}{100}$ inches as against $2\frac{54}{100}$ inches in the Walker system. The limited distance of these points of contact from base of pinion teeth, and the increased thickness of same, gives a pinion much more advantage in the Walker than in the Willis system. In the same proportion, as the points of contact are nearer the base of pinion teeth, so they will be farther from the base of the wheel teeth, thus bringing the greatest strain or leverage on the wheel teeth, which will, in all cases, be better able to bear it than the pinion teeth.

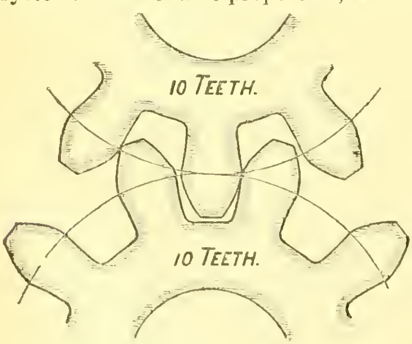


FIG. 9.

Figs. 7 and 8 represent a pair of wheels of 200 teeth, both being drawn at the same relative position to each other, Fig. 7 being from the Willis system and Fig. 8 from the Walker system. The angle lines form tangents to the points of contact and show clearly that there will be an excess of thrust on the teeth, also the bearings, in the case of the Willis wheels. At the point *a*, Fig. 8, the teeth will be seen to be much nearer contact than in Fig. 7, showing that there are more teeth in contact, or that they remain in contact longer.

Figs. 9, 10 and 11 are illustrations of extreme numbers of teeth in gear, determined by this (Walker's) system. It will be observed that the form of teeth in the pinions of 10 teeth are all alike; also, the form of teeth for

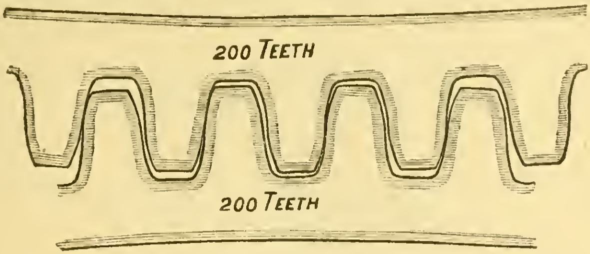


FIG. 10.

gears of 200 teeth are alike. These two extreme numbers of teeth have been selected for illustration, as they are really the worst cases to determine. All other numbers of teeth are as the difference of their diameters, the difficulties lessening as the gears approach an average of the two extremes. In delineating the forms of teeth and finding the respective radii for the average line, as explained in Fig. 3, the writer used templets of 6-inch pitch for gears of 10, 12, 15, 20, 30, 50, 100 and 200 teeth, also a rack. The forms of teeth were found for each gear by using pitch circles of 10 and 200 teeth respectively, as in Fig. 3, for the generating circles, they being chosen before as the limits. To determine the teeth of gears by this plan would be tedious. To obviate

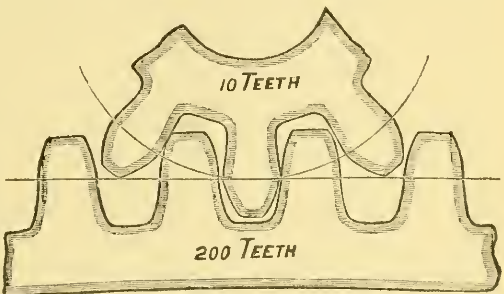


FIG. 11.

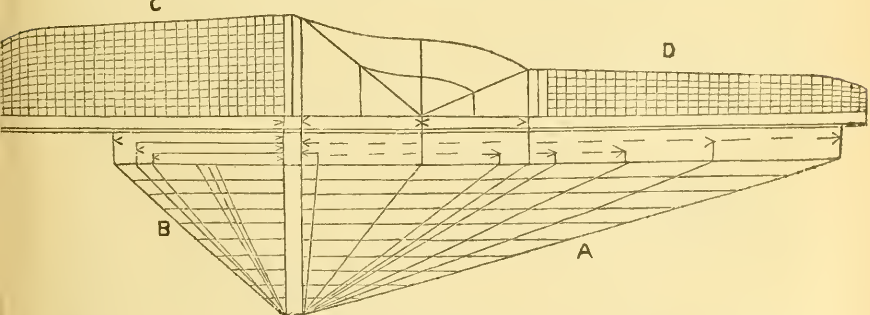


FIG. 12.

this the writer has arranged a very complete and convenient chart or scale, known as Walker's Wheel Scale, whereby any person with ordinary mechanical ability may delineate, in a few moments, the proper form of tooth for any particular gear needed.

Fig. 12 is an illustration of chart or scale. From the portion A we get the length of tooth for any gear; from the portion B we get half the thickness of tooth on pitch circle; from portion C we get half thickness of tooth at root for any gear; from portion D we get half thickness of

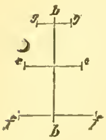


FIG. 13.

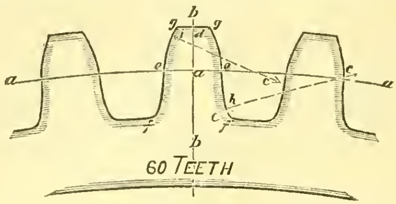


FIG. 14.

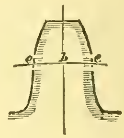


FIG. 15.

tooth at point. These half thicknesses are set off on each side of centre or radial line, as in Fig. 13.

Figure 14 is a complete illustration of three teeth determined from the scale for a spur gear of 6-inch pitch and 60 teeth. The pitch arc *a a* being struck with proper radius we draw radial line *b b*; from scale set off *a c* and *a d*, forming lengths of flank and face respectively; from scale set off *b e*, *b f*, *b g*, on each side of radial or centre line, forming thicknesses at pitch line, root, and point of tooth; then with radius *c h*, for flank of tooth, taken from scale for a gear 6-inch pitch and 60 teeth, intersect arcs at *c* from *e* and *f* on both sides of tooth. These intersections indicate position for path of centres for striking the flanks of the teeth. Then with a radius *c i*, for face of tooth, taken from scale for a gear 6 inch pitch and 60 teeth, intersect arcs at *c* from *e* and *g*, on both sides of tooth. These intersections indicate position for path of centres for striking the faces of the teeth. The fillets at the roots of teeth are struck with radii provided for on scale. In determining gears with less than 30 teeth, as in figure 15, arcs *e e* struck with radius equal to half thickness of tooth are used across pitch line, allowing the arcs forming flanks and faces of teeth to blend with them. The forms of teeth from this system are such as to roll easily on each other without jarring.

Joshua Rose after investigating this system, says in Cincinnati *Artisan* of Dec. 1st, 1879: "The general results obtained by the Walker system are, that in small gears there are more teeth in contact than would be the case if rolling circles, equal in diameter to the smallest gear of the set, were employed, while the point of contact, taken at any position of a gear and pin on, is nearer the base of the pinion tooth, giving a longer operative length of flank than would be obtained by striking the flank curves from a point on the pitch circle, instead of from a point on the addendum circle

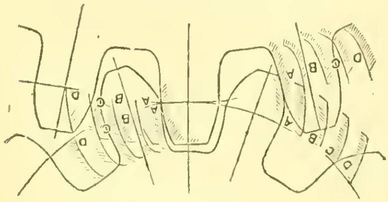


FIG. 16.

or point of the tooth." This addendum point was clearly illustrated at *e* in Figure 1. and *d* in Figure 2.

Fig. 16 is an illustration of my method of ascertaining whether a pair of gears will work together without making templets for that purpose.

All gears (irrespective of their diameter) working together make the same feet per minute, on their pitch lines; hence we set off *A. B, C, D*, as in Fig. 16, any equal distance apart on pitch circle of both gears, then with radii for faces and flanks of both gears describe arcs from *A, B, C, D*, always keeping one and of dividers on the "path of centres" belonging to that part of the teeth being described. The lines thus described will show the relative position of the teeth at various positions of the gears.

NOTES RELATING TO THE EARLY HISTORY OF TRANSPORTATION IN MASSACHUSETTS.

BY PROFESSOR GEORGE L. VOSE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read November 19, 1884.]

At the close of the last century two coaches and twelve horses were sufficient for the conveyance of passengers between Boston and New York, and a week of hard traveling was consumed in the journey. At the present time the two cities are connected by four lines of railway, over which not less than twenty-four millions of passengers are annually carried. In the year 1800 the whole freighting business between Boston and the interior was done by half a dozen wagons, which on the most important routes ran as often as once a week, and carried from one to two tons each. At the present time eight lines of railway terminate in Boston, over which not less than twelve million tons of freight are transported each year. It may be interesting to look at some of the intermediate steps in the process which in less than a hundred years has produced so great a change, and has wrought a social and commercial revolution as remarkable as any the world has ever seen.

There is little to be found in regard to the beginning of transportation in Massachusetts, except the advertisements in old papers, and the somewhat doubtful and contradictory statements of the "oldest inhabitants." The transition from the private to the public conveyance was a very gradual one. First, a horse was borrowed, then a chaise; then both horse and chaise; then, to meet a slowly growing demand, a horse and chaise were kept to be let; finally a driver was added, and the age of the stage-coach commenced. In the *Boston Evening Post* for 1767 we find during the months of August, September and October, the following advertisement: "Stage coach No. 1, kept by Thomas Sabin. Sets out every Tuesday morning from the house of Mr. Richard Olney, Innholder, at the coffee house, the sign of the Crown, in Providence, to carry travelers to Boston on the most expeditious and cheap rate. While in Boston he puts up at Mr. John Burrows', at the sign of the Lamb, where he will be ready to wait on all those who may be pleased to return with him on the Tuesday following. Said Sabin has provided himself with several sets of good horses for said purpose, and intends following the business all the summer season. All gentlemen and ladies may depend on the most ready observance of their desires by their very humble servant—*Thomas Sabin*."

In 1770 Benjamin Coats, landlord of the Ship Tavern, on North street,

Boston, gave notice that he had bought a new "stage-chaise" which would run between Salem and Boston, so that he will be able to carry and bring passengers, bundles and the like every day except Sunday. In 1771 Benjamin Hart advertises that he has left riding the single horse post between Boston and Portsmouth, and now drives the post-chaise lately improved by John Noble. He sets out from Boston every Friday morning, and from Portsmouth every Tuesday morning following. The above conveyance, he says, has been found very useful, and the more so as there is another "curricle," improved by J. S. Hart, who sets off from Portsmouth the same day this does from Boston, by which opportunity offers twice a week for travelers to either place.

The traveling between Boston and New York would seem to have been in anything but a satisfactory condition towards the end of the last century, if we may judge from the description of the journey by the late President Quincy of Harvard College. "The carriages," he says, "were old, and the shackling and much of the harness made of ropes. One pair of horses carried us 18 miles. We generally reached our resting place for the night, if no accident intervened, at ten o'clock, and after a frugal supper went to bed with a notice that we should be called at three next morning, which generally proved to be half-past two, and then, whether it snowed or rained, the traveler must rise and make ready, by the help of a horn lantern and a farthing candle, and proceed on his way over bad roads, sometimes getting out to help the coachman lift the coach out of a quagmire or rut, and arrived at New York after a week's hard traveling, wondering at the ease as well as the expedition with which our journey was effected."

Later in the last century a decided improvement had been effected, as shown by the following advertisement in the *Columbian Centinel* for April 24, 1793. "Boston and New York Stages. The subscriber informs his friends and the public that he, in company with the other proprietors of the old line of stages, has established a new line from Boston to New York for the more rapid conveyance of the mails. The stage-carriages of this new line will be small, genteel and easy, in which but four inside passengers will be admitted, with smart, good horses and experienced and careful drivers. They will start from Boston and New York on the first Monday in May, and continue to run three times a week until the first of November, and will leave Boston every Monday, Wednesday and Friday at 4 o'clock A. M., and arrive at New York in three days and a half from their departure. They will leave New York on the same days at one o'clock P. M., and arrive at Boston on the fourth day from their departure at seven o'clock P. M. The number of passengers being so small, conveyance so agreeable and rapid, the price for each passenger will be 4d. per mile, with 14 lbs. of baggage *gratis*, and as the proprietors have been at such great expense to erect this line, they hope their exertions will give satisfaction and receive the public patronage."

Besides the above "Fast Line," the proprietors advertise another line occupying four days for the trip, the price being 3d. per mile per passenger, with 14 lbs. of baggage *gratis*, and for every 150 lbs. of baggage the same as a passenger.

Departing from Boston in another direction we find in the same year

the following: "New Line of Stages. Public notice is hereby given that a line of stages for the conveyance of passengers is now established between the town of Boston and the country northwest thereof as far as Walpole, New Hampshire, which bids fair to be of great public utility. The arrangements thereof are as follows: A stage-carriage drives from Robins' tavern at Charles River Bridge on Monday and Friday in each week, and passing through Concord and Groton, arrives at Wyman's tavern in Ashby in the evening of the same day, and after exchanging passengers there with the stage-carriage from Walpole, it returns on Tuesdays and Saturdays by the same route to Robins'. Another carriage drives from Mann's tavern in Walpole on every Monday and Friday, and passing through Keene, arrives at Wyman's in the evening of the same day, and after exchanging passengers with the carriage from Charlestown, returns on Tuesdays and Saturdays by the same route to Walpole. The Charlestown carriage drives also from Robins' on Wednesday in each week, and passing through Concord arrives at Richardson's tavern in Groton on the evening of the same day, and from thence returns on Thursday to Robins'. Each of the above carriages start uniformly at six o'clock in the morning. The rate of passage in all of the above mentioned carriages is two pence half-penny a mile."

Turning in yet another direction, we find in April, 1793, this advertisement: "Haverhill Stage-coach. Notice is hereby given that the Haverhill stage-coach is complete, with genteel curtains and cushions, and a pair of able horses, ready for service. This stage sets out from Chadwick's Ferry in Bradford on Tuesday at six o'clock precisely, and it expects to arrive at Mr. Isaac Abbot's in Andover before eight, and arrive at Jones' in Wilmington by nine, and at Boston before one. This stage on return sets out from Mr. Nathaniel Peabody's in Union street, Boston, at six o'clock on the Friday following, and reaches Haverhill before one. This route will be continued every week on the days and hours in each as above mentioned. N. B.—It is intended in a short time that this stage performs this route twice in a week. When this takes place, notice will be given. The fare, 3d. a mile."

On the following July (1793) competition seems to have commenced, as we find the advertisement below: "The Real Haverhill Stage. Agreeably to my former advertisement I now inform the public that my stage will run twice a week from Haverhill to Boston. * * * * Furthermore, I am prepared and determined this stage shall run three times a week whenever business shall require it. The present fare I put at 6s. from Haverhill to Boston and 4s. 6d. from Andover, for I am determined the public shall be well served. I am sensible the sum is by no means sufficient, but a certain Mr. A. has set up in opposition a stage, long after mine was set up, and underbid a reasonable price, this having a natural tendency to deprive the public of having any stage and defeat the business. I therefore, in my turn, have underbid him. *Samuel Blodget.*" To the above Mr. Joseph Adams replies, "That if the great Judge Blodget means by the Real Haverhill Stage that it is something more than shadow or appearance, the subscriber will not contend that point with him, supposing if it had been a cheat it must have been discovered a number of years since from the antiquity of its appearance," and adds, "Should

passengers suppose that the difference in price is greater than the difference of accommodation between the two carriages, it shall be left with them to make it."

Upon the Providence line again we find in the same summer (1793) the germ of competition, followed by consolidation, as follows: "Boston and Providence Stage. The subscriber informs his friends and the public that he, for the more rapid conveyance of the mail stage carriage genteel and easy, has good horses and experienced, careful drivers. They will start from Boston and Providence, and continue to run three times each week until the first of November. Will leave Boston every Monday, Wednesday and Friday at five o'clock A. M., and arrive at Providence the same day at two o'clock P. M. The price for each passage will be nine shillings only, and less if any other person will carry them for that sum. Twenty pounds of baggage gratis. THOS. BEALS." In the same paper we have the following: "Boston and Providence Stages. Israel Hatch most respectfully informs the public that his line of stages will run every day in the week excepting Sunday. His coaches leave Boston at five o'clock A. M., and arrive at Providence at two o'clock P. M. Twenty-four excellent horses, six good coaches and as many experienced drivers, are already provided. The horses will be regularly changed at the half-way house in Walpole. The price from Providence to Boston is only one dollar, which is one-half the customary price, and three shillings cheaper than any other stage." The subscriber adds that he is "determined, at the expiration of the present contract for conveying the mail from Providence to Boston, to carry it *gratis*, which will undoubtedly prevent any further underbidding by the envious." A little later in the season in reply to the above Mr. Beals assures the public that envious motives were not the causes that induced him to erect his line of stages. He is induced to believe that were the public made acquainted with the impositions practiced by a certain line on private passengers, they would not be trusted with any thing of such importance as the public mails, even on their much reduced and moderate terms." In August of the same year a consolidation of the Hatch and Beals interests seems to have taken place, as we find the Providence stages run by the two proprietors in common, the fare being $2.50, the public as usual paying for the previous competition; and in the winter following the stages are leaving Boston every Monday and Thursday at six o'clock A. M. and returning from Providence every Wednesday and Saturday at 5 A. M. and the public is notified that the proprietors are under the necessity of raising the fare to $3.00 in consequence of the enormous price of hay and grain.

Coming down a little later, we find increased accommodation and higher rates of speed. Thus in the *Centinel* for June 10, 1814, we have the following: "Boston and Providence. New Line. The subscribers respectfully inform their friends, and the public in general, that they have commenced running a line of stages between Boston and Providence. From the great increase of travel on this road, the accommodation afforded by a new line must be obvious to every traveler. * * * * The regular stage leaves Boston and Providence every day at 9 o'clock, dines at Mr. Polly's in Walpole, and arrives at Boston and at Providence

at six o'clock P. M. Fare $3.00. Customary baggage allowed. PALMER, DAVENPORT & Co."

A decided improvement takes place also in the New York line, as seen by the following (*Col. Cent.*, July 2, 1814): "Public Accommodation. New York and Boston. New Line Enterprise. This line is advertised to run every day. Sundays excepted, and to make the journey in two days, as follows: Leaves the Exchange Coffee House, Boston, every morning (Sundays excepted) at 3 o'clock, passes through Dedham, Medfield, Mendon, Douglas, dines at Thompson, then proceeds through Ashford and Tolland and arrives, same evening, at Hartford to lodge. Leaves Hartford every morning at 3 o'clock, passes through Meriden and breakfasts at New Haven; then passes through Bridgeport and Stamford and dines at Horse Neck, and arrives at the City Hotel in New York at 8 o'clock same evening to lodge, being only two days from Boston to New York. * * * In addition to the stage, the proprietors have established a line of Post-chaises on the same road, between Boston and New York, for the accommodation of gentlemen traveling with or without their families. They can be furnished with carriages to start any hour of the day, and to go faster than the mail, or at their leisure. Gentlemen traveling in their own carriages can have post-horses; all of which shall be on the most reasonable terms."

On the eastern side of Boston staging began to be systematized as early as 1796, the pioneer of the Boston and Portsmouth line being Benjamin Hale, of Newburyport. Mr. Hale is said to have invented the trunk-rack, by which the baggage was made to ballast the coach. In 1818 the Eastern Stage Company was chartered in the State of New Hampshire. The capital stock was fixed at first by the company at 425 shares, of one hundred dollars each, and the charter extended for twenty years. The main route of this line in 1818 was as follows: A coach left Portsmouth for Boston at 9 o'clock A. M., dined at Topsfield, and then ran through Danversport and Salem to Boston, and back the same way the next day, dining at Newburyport. In 1825 the directors had established a sinking fund, and had carried $1,000 to that account, had declared a semi-annual dividend of four per cent. and had created 75 new shares, making up the full 500 allowed by the charter. The second dividend for this year was 6 per cent., and in 1826 eleven per cent. was divided. In 1828 the shares were at a premium of $50, and a semi-annual dividend of 8 per cent. on $150 was made. In 1830 the company was incorporated in Massachusetts with a capital of $100,000. In 1832 it was running coaches from Concord to Portsmouth, from Dover by two routes to Newburyport, from Portsmouth to Newburyport, Salem and Boston, from Salem to Haverhill and Lowell, from Gloucester to Ipswich, and from Lowell by two routes to Newburyport. In 1833 the company was free from debt, and owned 500 horses with equipment to correspond. In 1834 the stock stood at over $200 a share, par being $100. In 1835 the company was paying from $8,000 to $9,000 in tolls annually, and owned a large amount of turnpike, bridge. bank and hotel stock. It was over this line that Henry Clay was carried from Pleasant street in Salem to the Tremont House in Boston in sixty minutes, and upon this route too Daniel Webster was carried from Boston to Portland, to sign the Ashburton treaty, at the rate of sixteen

good English miles an hour. This period (1830 to 1835), saw the culmination of the stage business. On the introduction of railroads it soon declined, and except as the coaches became tributary to the railways they gave way to the improved mode of transport.

Soon after the close of the Revolution the inhabitants of Boston began to appreciate the fact that that city labored under a great natural disadvantage. It had no direct means of communication with the interior. The natural lines of water transport led away from Boston rather than toward it. The area drained by the Connecticut found naturally an outlet through Hartford to New York. The Blackstone valley drew the traffic from Worcester County to Providence, while the large interior of New Hampshire naturally followed the course of the Merrimac to Newburyport. The success of the Duke of Bridgewater's canal from Liverpool to Manchester suggested that mode of interior communication as being well adapted to this country, and as early as the year 1791 we find General Henry Knox engaged in making surveys for a canal from Boston to the Connecticut River, and in 1792 getting a charter for carrying out that work. This document is interesting, both from its antiquity and from the nature of its provisions. The charter, which is dated March 8th, 1792, and which was approved by Governor Hancock two days later, incorporates Henry Knox, John Coffin Jones, David Cobb, Benj. Hichborn and Henry Jackson, by the name of the Proprietors of the Massachusetts Canal, and gives them the exclusive right for the term of fourteen years to establish a navigable canal from any part of the Connecticut River between the town of Springfield and the northern limits of the State, to the town of Boston or the waters surrounding it, and also to open any branches from said canal to communicate with any other parts or places in the Commonwealth, and to take, occupy and possess exclusively, in fee simple or otherwise, any land or water which may be necessary to complete said canal and the appendages thereof, * * * provided the land so taken shall not exceed 25 feet on either side. The company is also authorized to collect a toll of not more than sixpence per ton per mile for all quantities not less than a quarter of a ton, exclusive of a certain toll for passing locks. The rights above are given to the corporators forever, provided that the General Court shall at all times after the expiration of 70 years from the completion of the canal alter, regulate and determine the toll thereof, and the Commonwealth shall be entitled to receive one-quarter part of the net proceeds thereof forever. It was further provided that when, and so often as the proprietors should finish a proportion of said canal equal to ten miles in length, they should receive toll on the same. It was provided further, that if the corporation should not complete at least ten miles of the canal within five years from the passage of the act, the Legislature had the right to incorporate another company for the purpose of completing the work.

In a formal contract made between Henry Knox and John Hills, both of Philadelphia, it is agreed that Mr. Hills is to make such examinations of the country from the Connecticut River to the tide-water navigation of Charles River at Watertown, for the purpose of opening an inland navigation, as shall be indicated by Henry Knox; that the results of the surveys and levels, together with all observations arising out of the case,

shall be delivered to the said Henry Knox, and that no copies thereof shall be delivered to any other person on a penalty of a thousand dollars. For this service Mr. Hills was to receive the sum of three dollars a day "for his trouble and expenses," provided he is not over 90 days about the work. The correspondence between Gen. Knox and Mr. Hills shows that the surveys were going on during the summers of 1791 and 1792. These surveys were most likely no more than rough reconnoissances, as Mr. Hills says of his work during the summer of 1792 that he has used no level during the season, but judges that if he finds water on the summits there will be no trouble in carrying it when it is wanted. The summer of 1791 was spent in examining the Chicopee River from above Springfield to Palmer, and in trying to find a route from that point in a generally easterly direction to strike the Charles River below the Falls. The survey seems to have followed the Chicopee to East Brookfield, and thence through Spencer into Paxton and Holden, when it reaches the headwaters of Halfway River (Tatnick Brook), which it followed past the Stone House Mountain to the Boston road, and so on down the headwaters of the Blackstone, through Ward (Auburn) and Sutten to Grafton. The examination also continued through Westboro', Hopkinton, Framingham and Natick, the attempt being made to reach Charles River below the Falls. This was not successful. In a letter to Gen. Knox, Mr. Hills reports that he was in great hopes to strike the Charles below the Falls, but that he has made four attacks and as often been repulsed by "a cursed rocky boundary" within a few miles of the river. He therefore concludes to turn off from Nonesuch Pond through Ward's and Bullard's Ponds, and so to Charles River in Dedham, and thence down the river, a route involving of course locking around the Falls. Later in the season we find him exploring through Dover and down Charles River to Millbrook, and thence by Neponset River to tide water.

In the summer of 1792 Mr. Hills was engaged in examining Miller's River and the country from Worcester through Holden, Boylston, Sterling, Princeton and Westminster to Ashburnham, and also through Lancaster, Leominster and Fitchburg, and he writes that he expects soon to explore, to see in what direction he can get to Concord River. Later we find him reconnoitering from Worcester to Long Pond, and thence by Sewall's and Spruce Ponds and Muddy River to Nashua River in Boylston, and down this river to Lancaster. Surveys were also made through Lexington, Cambridge and Charlestown to the Mystic River in Medford.

Mr. Hills does not seem to have got so far as to attempt any estimates of the cost of a canal. From the general character of his letters he would seem to be merely a common land surveyor, and not at all competent to undertake any work of engineering. Among the papers of Gen. Knox, however, there is a good deal of correspondence in regard to canals. He seems to have been collecting information from all sources, among which is the following: "Expense of canal. A mile of canal, 5 yards wide at bottom, 8 at the surface of the ground, and 1 deep, makes in one mile 11,440 cubic yards. In hard ground at one shilling a yard, £572. In moderate ground at 8d., £381; and in soft ground at 4d., £190. A man's day's work is reckoned at four shillings." A detailed estimate is

also given for a lock of timber 100 feet long in the chamber, 12 feet inside, with a fall of 8 feet, the whole cost being £100.

There is no evidence that the Massachusetts Canal Company took any active steps beyond the survey above referred to. The interest in the project seems to have been confined to Gen. Knox and a few of his friends, who were deeply impressed with the importance of a means of communication between Boston and the interior. That the explorations for such a work should have been made without the use of a level, and that $2,000 a mile should have been thought sufficient to carry out the plan, shows how little conception of the real nature of the undertaking its projectors had. The principle, however, which moved this small company so many years ago was the same that in later times resulted in the construction of the vast railway system which now connects Boston with the central and western parts of the country, and which has done so much to develop the resources of the State.

The pioneer work of actual internal improvement in Massachusetts, if not in America, was the Middlesex Canal, the inception and execution of which was due mainly to one of the most distinguished men of the last century, James Sullivan. He saw, upon the map, the Merrimac River reaching far up into the heart of a great State, which lacked only the means of sending its products to market to set in motion a thousand wheels of industry. "The connection of Boston," says Mr. Amory, in his excellent life of Sullivan, "by a line of navigable waters with New Hampshire and Vermont, and perhaps with Canada, became early for Sullivan a favorite project. The Merrimac, after issuing from Lake Winnipesaukee, 120 miles from Boston, ran southerly within 27 miles of that capital, and then turning abruptly to the northeast discharged itself, after an obstructed course of 50 miles, at Newburyport. Between Concord, in New Hampshire, and Windsor, in Vermont, the Sunapee Lake gave facility for connecting the Connecticut and the Merrimac, and the latter could be made navigable by locks at low cost. Should the undertaking succeed between Concord and Boston, the gradual increase of population and traffic would in time warrant its extension to the Connecticut, and perhaps to the St. Lawrence. The first step was a canal from Chelmsford to Boston." In the month of May, 1793, several gentlemen, prominent among whom were James Sullivan, Loammi Baldwin and Jonathan Porter, associated themselves for opening a canal from the waters of the Merrimac, by Concord River or some other way, through the waters of Mystic River to the town of Boston; and a committee proceeded at once to obtain a charter from the General Court, which was signed by Governor Hancock on the 22d of June, 1793. The company organized by the choice of James Sullivan as president, and Loammi Baldwin and John Brooks as vice-presidents, and proceeded at once to make the necessary surveys to find the most eligible route between Medford River and the Merrimac. An accurate survey in those days was almost unknown in this country, and a leveling instrument was an unheard-of thing. In January, 1793, Mr. Sullivan wrote to Gen. Knox: "We are under the necessity of procuring a man who is skilled in the business of canaling, who can point us to the place where, under all circumstances, the canal ought to be cut. We hear that such

a person is in Philadelphia, who has come to America on the invitation of Mr. Morris. We beg the favor of your inquiring whether such an artist is there, and whether we can obtain his aid." The "artist" referred to was Mr. Samuel Weston, an engineer brought up in England under James Brindley. A preliminary examination of the ground was made in the summer of 1793 by Mr. Samuel Thompson, of Woburn. He appears to have made a very careful study of the country, but was not provided with instruments of sufficient precision to obtain the elevations accurately. In March, 1794, the directors voted to send Loammi Baldwin to Philadelphia, that he might try to get Mr. Weston to make the survey for the canal, which he succeeded in doing. The surveys were commenced in July, and on the 2d of August, 1794, a full report was made upon the work. It was found that the route of the canal would be crossed in Billerica by the Concord River, which at that point was 107 feet above tide water at Boston, and 27 feet above the Merrimac at Chelmsford, being at the summit of the canal, and able to supply water in both directions.

The work of building the canal was commenced in the spring of 1795, under the direction of Col. Loammi Baldwin the elder, and continued in the face of numerous difficulties until 1803, at which time it was so far completed as to be navigable from the Merrimac to Charles River. The canal was 18 feet wide on the bottom, 30 feet wide at the water-line and 4 feet deep. The locks were 11 feet wide and 76 feet long, with an average lift of about 7 feet. Some of these locks were made of wood, and others of stone. In the wooden locks the side walls, which were of wood, were inclosed between rough walls of masonry placed a few feet back of the timber-work. The masonry was thus the retaining wall for the earth, while the timber formed a tight box for the water, the two walls being well braced apart by struts of wood. In this way expensive masonry was avoided, but the cost of maintenance in after years was increased.

Commencing at the Merrimac River in Chelmsford, at a point just above the present "Middlesex" station of the Nashua and Lowell railway, the canal ascended through a connected flight of three stone locks, the location of which may plainly be seen by the deep depression on the line of the canal between the hotel and the railway, and directly in front of a small house, which was formerly the canal office. Passing under the main street at Middlesex village, and over an aqueduct across Black Brook, it continued across the long swamp to River Meadow Brook, and thence to Billerica Mills, where it entered the Concord river mill-pond through a stone guard lock, which is still standing in the yard of Governor Talbot's mill. The tow-path was carried across the pond on a floating bridge or raft, and the canal, passing out through another guard lock just south of the road, continued on to Shawsheen River, which was crossed by a wooden trunk about 40 feet long, supported by two abutments and a pier of stone. This masonry is still to be seen directly below the common road, and from its considerable height must have been one of the most imposing works upon the line. Half a mile further south was Nichols' lock, and a mile and a half further Gillis' or Jacques' lock. About two miles further, and near the Poor Farm, in Wilming-

ton, the canal crossed Maple Meadow Brook, and made an abrupt bend called the Ox-Bow. A mile further south the canal entered the town of Woburn, running along close to the west side of the traveled road, passing under it near Wilson's tavern, running a little east of the village of North Woburn, crossing the road nearly in front of the Baldwin Place, and continuing through the western part of Woburn village, passing in the rear of the present public library, it soon after reached the site of one of the chief engineering features on the route, the Horn Pond or Stoddard's locks. At this point the canal made a descent of 50 feet by three sets of double locks, the middle set being separated from that above and below by a basin-like expansion or widening of the canal, by which the draft of water by locking was equalized. Half a mile further, and just south of the crossing of the outlet stream from Horn Pond, was a stone lock, and a mile and a half further, and just north of Abbajona River, were Gardner's locks, which were double. From this point the canal ran close along the shore of Medford Pond, passed through the fine grounds of Peter C. Brooks, where there is still standing a handsome elliptic stone arch built to carry a farm road over the canal. Half a mile further south was Gilson's lock, and directly afterward the aqueduct over Mystic River. The present highway bridge rests on the piers of the old aqueduct, which have been built up to suit the grade of the present road. From this point the canal turned east, passing under the Lowell Railroad (though the canal was built first). The wing walls of the way under the railway may still be seen cropping out of the embankment, and the bed of the canal is quite plain to the eastward of the railroad for some distance. Just in front of the old Royal House the canal passed under the road, now called Main street, and at this point a side or branch canal about a fourth of a mile long, with a lock and a basin at the upper end and a lock at the lower end, led to the river, passing under the old Medford turnpike, and entering just below the bridge. This branch was used for transferring ship timber to Mystic River. From this point the canal followed very nearly the base of the high land, passing through what is now the Mystic Trotting Park, at the southwest corner of which it is plainly seen, then running to the sharp bend in the river at the old toll-house, it turned to the south and passed nearly through the middle of what is now Broadway Park, curved around to the base of Mt. Benedict (Ploughed Hill of Revolutionary times), and, crossing under Medford turnpike just at the foot of the present Austin street, to the north of which the bed may still be traced by the willows that grew along the bank, it reached a lock just east of the old road over Malden Bridge, and, curving around, passed the present locations of the Boston & Maine and Eastern railroads a little north of Main street, where on the east side of the railroads, the canal is plainly seen just back of the lead factory, and, crossing under Main street, it passed through a lock and entered the mill-pond, from which the boats were let into the Charles River by a lock with double gates arranged to work in either direction according to the state of the tide.

Once in the river it was easy by poling, rowing or sailing to reach any part of Boston; but the canal proper occupied the area on which the Boston and Maine depot now stands, Canal Street being directly along-

side of it. Hale's Map of Boston shows the old mill pond filled up, except the canal, which extended from Causeway street to Haymarket square, and which was bridged over at Causeway and Traverse streets. This part of the canal was connected with the harbor, near what is now North Market street, by a waterway which followed nearly the present line of Blackstone street, and was large enough for canal boats, and was bridged over at Hanover and Ann (North) streets. It was through this passage that nearly all the stone for Quincy market, which came over the Middlesex canal from Concord, N. H., was brought. The passage by Mill Creek is shown on Carleton's Map (1800).

The length of the canal was 27 miles ; the rise from the Merrimac River at Chelmsford to the Concord River mill-pond at Billerica was 27 feet, and the fall from the mill-pond to Charles River 107 feet. There were in all 20 locks, 48 bridges over the canal, and 7 aqueducts. The work was under construction from 1795 to 1803. The cost was about $500,000, of which about one-third was for land damages.

The traffic, which was mostly freight, was carried in flat-bottomed boats, with a rectangular midship section reduced a little toward the ends. By the regulations of the canal, boats were required to be not less than 40 feet nor more than 75 feet long, and not less than 9 feet nor more than 9½ feet wide. Each boat was drawn by one horse, the towing line being attached to a short mast, which was placed a little ahead of the centre. The crew consisted of one man to drive and one to steer, except in the case of boats running up to Merrimac River, which had one man to steer and two to pole. These boats carried from 16 to 30 tons, and drew about 2½ feet when loaded. Freight boats were required to make 2½ miles an hour, and passenger boats 4 miles. Boats of the same class going in the same direction were not allowed to pass. The usual time for freight-boats between Boston and Lowell was about 18 hours for the passage up and 12 hours coming down, and for passenger boats 12 hours going up and 8 hours coming down. These last, which were called packets, were shaped much like the present Erie Canal boats, and had a covered cabin extending the whole length, excepting a small standing room at each end for working the boat. At first there were two of these packets, one running up and two other down daily; but this not proving profitable, one was taken off, the remaining one running up one day and down the next. A horse could draw 25 tons on the canal as easily as one on the common road. Coal, salt, slates, raw cotton and imported goods were carried to the interior, while lumber, wood and country produce came to the city. A great many rafts of lumber and large quantities of ship timber were brought down the canal, a single yoke of oxen drawing no less than 100 tons, a load which would have required 80 teams on the common road. These rafts were 75 feet long and 9 feet wide, and were generally united into "bands" of from seven to ten rafts. The company's charter allowed a toll of one-sixteenth of a dollar per mile for every ton of goods carried in the boats, and the same for every ton of timber floated in rafts. The actual rates ranged from $1 to $2 per gross ton for the 27 miles from Boston to Lowell.

Although the Middlesex Canal was completed in 1803, great expense was incurred for many years, owing to imperfections in the banks and

other parts of the work, and nearly the whole income was expended in additions, alterations and repairs, so that no dividend was declared until Feb. 1st, 1819. One hundred assessments were put upon the shares, which, with interest added to the above date, amounted to $1455.25 on each share, making the whole cost of the canal $1,164,200. From 1819 to 1843 there was paid in dividends $504 a share, averaging $20.16 per annum, being an interest on the cost of about $1\frac{39}{100}$ per cent. per annum. From the year 1819 to the time when the Lowell railroad went into operation the receipts regularly increased, so that the dividends rose from $10 to $30 a share. The year the Boston & Lowell Road was opened the receipts of the canal were reduced one-third, and when the Nashua & Lowell road was opened they were reduced another third. The receipts of 1842–43 were not enough to cover the cost of repairs and current expenses. After 1846 the traffic was small, though boats continued to run until 1852. In 1859 the charter was declared forfeited. The property was finally disposed of for about $130,000, and after the final dividend little more than the original assessments had been returned to the stockholders. When the Middlesex Canal went into operation it was the greatest work of internal improvement in America. It had been 22 years in operation when in October, 1825, DeWitt Clinton made his triumphal passage from Lake Erie to the Hudson River. Like many more recent works it produced a large indirect benefit. It was said by Daniel Webster to have added $5,000,000 to the value of the New Hampshire forests.

Closely connected with the Middlesex Canal, and making an important part of the same system of transportation, was the Merrimac Boating Company, known later as the Concord Boating Co. By a series of locks and short canals the Merrimac River was made navigable as far as Concord, N. H. The principal works along the river were the Bow, Hooksett, Amoskeag, Union and Wicasee canals. By this system of improvements a water route of 57 miles was added to the length of the Middlesex Canal proper, making 84 miles in all from Boston. Over this route a large amount of freight was carried for many years, and upon this line of navigation a very complete system for conducting operations was originated. In a report made by a committee of the directors of the Middlesex Canal in 1815, the opinion is given that the Merrimac River improvement is necessary to the final success of the Middlesex Canal; that its usefulness is sure to increase largely, and it was further suggested that an extension of the system through the Contocook River to Sunapee Lake, and thence by Sugar River to the Connecticut at Claremont (a route now followed by the Concord & Claremont Railway) may be practicable, by which it was reckoned that the water carriage from Boston would be increased to 300 miles. Indeed, shortly after the date of the above report the Legislature passed a resolve appointing Professor Farrar, of Cambridge, and Loammi Baldwin to survey this route at the public expense, which was done, and but for the introduction of railways the work would no doubt have been carried out.

The Blackstone Canal, connecting the cities of Providence and Worcester, was first proposed by John Brown, of Providence, who at a very early date had a survey made and secured a charter from the State of Rhode Island. He was, however, unable to obtain one from Massa-

chusetts, and the project slumbered until 1822, when it was again taken up both in Providence and in Worcester, and the distinguished engineer of the middle division of the Erie Canal, Benjamin Wright, was employed to make the necessary surveys. He proposed a canal 32 feet wide at the top, 18 feet at the bottom and 3½ feet deep, with locks 10 feet wide and 70 feet long. The length was 45 miles, with 62 locks, making a descent of $451\frac{61}{100}$ feet, and the estimated cost was $323,319. Upon this the committee having the matter in hand observed: "Such is the report of a skilled engineer, and such is the mathematical certainty with which questions such as came under the consideration of Mr. Wright are capable of being investigated, that the result obtained by the surveys of scientific men may safely be considered as approximating very nearly to the truth." In this report the cost of transportation, exclusive of tolls, was reckoned at one cent per ton per mile, or $1 a ton for 100 miles, while the usual cost of conveyance was $1.25 per cwt., or $25 a ton for 100 miles; and the report continues: "If any one doubts whether the canal will be useful to him, let him remember that his goods will bear the same price in the market whether he pays $10 or $2 for transportation, and the only question with him will be whether he chooses to make or to throw away money."

The work on this canal was completed in Rhode Island in 1824, and in 1826 it was commenced in Worcester. In 1828 the first boat was received into the upper basin near Lincoln Square. The length was about 50 miles, and the cost $750,000, more than half of which was raised in Rhode Island. Traffic continued on this canal until the introduction of railways, when in 1844 the company got the right to sell out to the Providence and Worcester Railroad, the line of which for a considerable part of its length corresponds very nearly with that of the canal.

In the year 1825 the Legislature of Massachusetts, in accordance with a petition from many prominent men, provided for a commission "to ascertain the practicability of making a canal from Boston Harbor to the Connecticut River, and of extending the same to some point on the Hudson River in the vicinity of the junction of the Erie Canal with that river." The commission consisted of Nathan Willis, Elihu Hoyt and Gen. H. A. S. Dearborn; and Loammi Baldwin, Jr., was appointed to make the surveys. The commissioners found it necessary to examine four entire routes from Boston to the summit between Boston and the Connecticut River, two from thence to the Connecticut, one by the way of Worcester, and one by the way of Fitchburg, and two from the Connecticut to the Hudson, as well as several lateral deviations. The northern route, which is the one shown on Mr. Baldwin's plan, and which is almost exactly the present route of the Fitchburg, Vermont and Massachusetts and Troy and Greenfield railroads, was regarded as the best; first, because the continuation of that route reached the Berkshire Hills at the best point for a passage, and second, because it was feared that if the canal ran through Worcester to Springfield, boats having passed down the Connecticut to Springfield would keep on down the river instead of going to Boston, and thus the country above Miller's River, instead of finding a market at Boston, would go elsewhere. From the Connecticut to the Hudson there was but one point where the Berkshire

range could be passed, and that was where the Deerfield on the east and the Hoosac on the west were only about four miles apart. From Boston to the Connecticut River the route proposed passed from the Mill Dam in Boston (where Mr. Baldwin suggested a tidal basin for vessels) through Brighton, Watertown, Waltham, Weston and Lincoln, to Lee's Bridge, on Concord River, and thence through Concord, Acton, Littleton, Groton, Shirley, Lunenberg, Fitchburg, Ashburnham and Winchendon, to Miller's River, and so on by Royalston, Athol, Orange, Wendell and Montague to the Connecticut; thence up the Deerfield to the great bend near Rice's tavern, from which point it was proposed to tunnel the Hoosac Mountain to reach North Adams, and then to continue by the Hoosac Valley to the Hudson River. With regard to the Boston end of the work the report says: "The canal ought to terminate in a capacious basin east of Washington street, where the communication may be easy between sea vessels and canal boats; and to effect this an enclosure with lock gates should be formed for the admission of ships or smaller vessels to the surface of the basin, kept nearly on the same constant level. From this a canal may extend across to Wheeler's Point (foot of Beach street) and thence to India wharf. Another may be carried from the basin across Washington street and along the foot of the common, on the site of the old rope-walks, to West Boston or even to Cragie's Bridge."

The rise and fall of the canal from Boston to the Connecticut River was 1,956 feet, calling for about 400 locks; and the estimated cost of this part of the work, 100 miles, was $3,000,000. The estimated cost of the line from the Connecticut to the Hudson River, 78 miles, was $3,023,172; of which the tunnel (4 miles long) was reckoned to take $230,208 per mile, or $920,832 for the whole length, the excavation being taken at $4.25 a yard. A scheme was also submitted for a passage of the Berkshire range, by means of locks, through the Stamford and Reedsborough gorge in Vermont. This route called for 220 locks in a distance of 18 miles, requiring two days for the passage, while the tunnel was reckoned to need only one and a third hours. The cost of the extra 18 miles of lockage was estimated at $2,090,000, or $1,169,168 more than the tunnel. The total estimated cost of the canal from Boston to the Hudson River by the tunnel line was thus $6,023,172. The size proposed by Mr. Baldwin for the canal was 28 feet at the bottom, 43 feet at the surface of the water, and 5 feet deep. The locks were to be 14 feet wide and 80 feet long. The report of the Commissioners was laid before the Legislature in 1826, but no more was done in regard to the canal.

Two years later (in 1828) surveys were made by James Hayward for a canal from Boston to the Blackstone Canal in Meriden, and thence by a very circuitous route to the Connecticut Valley, which made the distance from Boston to Springfield about 46 miles further than by the stage road, and from Boston to Worcester 26 miles further than by the turnpike. The cost of the work was estimated at about $12,000 a mile. While these various canal schemes were strongly recommended by the Governor in several messages, and while the originators and friends of the enterprises were active, intelligent, far-sighted and public spirited, nothing was done toward carrying out these works; chiefly, no doubt, on account of their

great cost, which, it was assumed, must be borne largely if not entirely by the State. It was just as well, however, that these works were not undertaken, for they would have been quickly replaced by the great improvement of this age, the railway. Upon the 4th of March, 1826, Gridley Bryant, who was well informed in regard to the early railway enterprise in England, had obtained a charter for a railroad four miles in length for the purpose of hauling stone from the granite quarries in Quincy to the Neponset River, to be used in the construction of Bunker Hill Monument. This work was commenced on the 1st of April, 1826, and on the 7th day of October following the first train of cars passed over the road. The success of the Quincy road (the construction of which was due entirely to the liberality and public spirit of Col. Thos. H. Perkins) and the movements in the same direction being made at the same time in England, did not fail to produce a strong sentiment in favor of the introduction of railways into Massachusetts; and in the latter part of 1826 a petition was presented to the Legislature by Col. Perkins and others, asking that a survey be made for a railway from Boston to the Hudson River. The two branches of the Legislature not being able to agree, a select committee of the House, consisting of Dr. Abner Phelps and Geo. W. Adams, of Boston, and Emery Washburn, of Worcester, was appointed to "consider the practicability and expediency of constructing such a railroad." This, it is stated, was the first concentrated action looking to the construction of a commercial railroad through the State. In January, 1827, the committee, after presenting numerous facts, expressed themselves as satisfied "not only of the practicability, but of the expediency of building a railroad from Boston to the Hudson River," and reported a resolve to appoint three commissioners and an engineer to make surveys, plans and estimates for such a work. The Legislature paid but little attention to the report, but appointed a Board of Internal Improvement of three members, who were to employ an engineer to examine routes for railroads and canals generally. This commission, for various reasons, accomplished very little. In January, 1827, the Legislature was again applied to by Josiah Quincy and others, and a resolve was passed providing for two commissioners and an engineer to procure plans and estimates for the best railroad route from Boston to the Hudson river, and $10,000 was appropriated for the work. The Board submitted its report in January, 1828, the effect of which was to substitute railways for canals, and to fix the policy of the State in favor of the railway system. In the following March a new Board of Internal Improvement, consisting of Levi Lincoln, Nathan Hale, Stephen White and others, was appointed to report upon the practicability and expediency of a railroad from Boston to the Hudson River, and from Boston to Providence. The surveys from Boston to the Hudson were made by James F, Baldwin, and from Boston to Providence by James Hayward. The report of the Board, which was prepared by Mr. Hale, with the reports in detail of the engineers, accompanied by plans and profiles of the several routes surveyed, were submitted to the Legislature upon Jan. 16, 1829. This document, several copies of which are preserved in the libraries of this city, was in every way an exceedingly able presentation of the claims of the railway, and shows so clear a com-

prehension of many of the principles involved that it may be proper to refer to it at some length.

"Before proceeding to a consideration of the advantages of the proposed railroads," says the report, "it seems important to fix some definite idea of the kind of structure which is believed to be best adapted to the purposes in view. The nature and objects of the undertaking demand that the work should be built of the most substantial and durable materials, and on a plan to accomplish the objects proposed in the most perfect and satisfactory manner, so far as this can be done without exceeding such reasonable limits of expenditure as shall be prescribed by the probable amount of income to be derived from it."

The report continues by stating that, "while the most approved railways in England are made of solid bars of wrought-iron weighing 35 pounds per yard, fastened each three feet to cast-iron chains attached to a foundation stone, the high price of iron in this country, and the great abundance and cheapness of fine granite on the line of the proposed roads suggests a different method, viz.: A continuous stone wall under each rail, laid deep enough to be below the action of frost, covered by a rail of split granite a foot wide and a foot deep, hammered on top and on the upper edge of the inner face, with a bar of iron for the wheel to run on, fastened to the stone at each foot by bolts or rivets, these rails to be placed at a distance of five feet, and the space between them to be filled within six inches of the upper surface with earth and gravel to form a path for the horses. The resistance to motion on such a road will be 11 pounds per ton of 2240 pounds upon a level, and about one pound per ton for each 2½ feet of rise per mile, or 11 pounds for each 26 feet of inclination. To compute the power which is required to move a given load on a railway of a given inclination, one pound per ton for each 2½ feet of rise per mile must be added for the ascending motion, and deducted for the descending motion. At an inclination of 26 feet per mile, the power of gravity is equal to the resistance from friction, and consequently to produce motion in an ascending direction requires double the power necessary for overcoming friction alone, and in the descending direction the resistance is overcome by the gravity, so that a very slight exertion is needed to produce motion. At any degree of inclination not exceeding 26 feet in a mile, the exertion required to move the load in ascending is just as much greater than it would be if the road were level as it is less in descending; so that the labor of a horse traveling on a road which is undulating, but which never exceeds an inclination of 26 feet per mile, is as much diminished in traveling in one direction as it is increased in the other, and the average exertion required is the same as if the road were level; but if the degree of inclination is more than 26 feet per mile the increased labor of ascending meets with no equivalent compensation in the diminution of labor in descending: so that the average exertion required is increased in proportion to the increased inclination beyond that limit.

The power of a horse is reckoned at 125 lbs. at an easy pace, going 20 miles a day, an exertion equivalent to drawing a gross load of 11 or 12 tons on a level railway, and as a horse can exert a greater force than that for a short time, it is assumed that if the road is nearly level for the most

part, with inclinations in either direction not much over 26 feet per mile, the average load for one horse may be taken at 10 tons. If the inclination for the most part exceeds 26 feet per mile, and ranges from that to 80 feet, the average load for a single horse should not exceed 5 tons; so that two horses should be allowed on the steep parts of the road for the loads which are suited to one on a level. While a level route is the best, it is not absolutely required. The railroad should, however, be brought as near to a level by the choice of the route, and by excavation and embankment, as is practicable at a reasonable cost, and without material deviation from a direct course. The degree of expense which may be advantageously incurred in reducing the inclination of the road must depend upon the nature and amount of the transportation to be expected upon it. It is only the shorter undulations that can be avoided by excavation and embankment. Where there are high ridges to be passed we must seek the route that gives the best surface, and where an elevation of the line cannot be avoided, we must apply a sufficient power for surmounting it. There are two modes of applying the additional power made necessary by the uneven surface of the country and consequent steep inclinations of the road. One is by selecting the route which affords the most gradual ascent to the summit to be passed, though it may not be in the most direct course, distributing the elevation as uniformly as possible, and after reducing every part of the road as nearly to a level as practicable within the proper limits of expenditure, by applying an additional traveling power for drawing the loads on all such parts of the road as need it; and the other by stationary power acting on inclined planes. The most simple mode of construction is to follow the route which requires no power but that of horses traveling on the road.

To determine the best route from Boston to the Hudson River surveys were made by Mr. James F. Baldwin. The first line started from Charles street, crossed Charles river to Cambridgeport and recrossed to Brighton, and passing through Brighton and Newton crossed Charles River again near the Lower Falls. From this point the line crossed the Worcester turnpike in Needham, and continued on the south side of that road at a short distance from it to Worcester, and thence through Leicester and Spencer to the Chicopee River in Brookfield, which stream was followed to Springfield. Crossing the Connecticut, it ran on the north side of Westfield River to Westfield and thence along the southern branch to the source of the western branch in Washington, and crossing the height of land between the Connecticut and the Housatonic, descended by a branch of the last named river to Pittsfield, and passed through Richmond, Canaan, Chatham, Schodack and Greenbush to the Hudson at Albany. Another line, more to the northward, passed through Cambridgeport, Watertown, Waltham, Weston, Sudbury, Marlboro', Berlin, West Boylston, Holden, Princeton, Rutland, Barre, Hardwick, Braintree, Ware, Palmer, Belchertown and Granby, to Rock Ferry on the Connecticut River in South Hadley. An examination was made for a continuation of this line, westward, from Northampton across the summit to the Hoosac River, through Williamsburg, Conway, Ashfield, Plainfield and Savoy, and thence to South Adams. The Savoy summit, however, was found to be 450 feet higher than the Washington summit. The

difficulty of descending the western side of the Hoosac ridge was considered a sufficient objection to all routes north of Northampton. A route was examined from Northampton through Southampton, Westhampton and Norwich to Norwich Bridge on the Westfield River, in hopes of finding favorable ground to unite the northern with the southern route at Chester; but the descent from the high ground in Norwich to the river was too great, being 563 feet in 235 chains. The next line surveyed was from Dalton by the Hoosac River through Cheshire, Adams, Williamstown and Pownal, and thence to Troy. A line was also run from West Stockbridge through Lee and Lenox to Dalton, there connecting with the original line passing round the south end of Stockbridge Mountain, and running up the Housatonic Valley. A route was also examined from the Housatonic River in Lee to Becket. Several modifications of the line between Boston and Springfield were also tried; but the line finally selected for estimates was that running through Worcester, Palmer, Springfield, Hinsdale, Dalton, Pittsfield, Richmond, West Stockbridge, Canaan, Chatham and Schodack, to the Hudson, being almost exactly the route of the present Boston and Albany Railroad. The length of the whole line was 198 miles, and the estimated cost $3,254,876 or $16,434 per mile, an amount of course far too small, even regarding the value of wages at that time.

The road was to have two tracks and to be 22 feet wide at the surface, with side slopes of one and a half to one, except in rock, where it was to be 20 feet wide, with sides nearly perpendicular. The track was to be made of flat bars of iron fixed to longitudinal stone sills set firmly on continuous stone walls, placed five feet apart, the space between the walls to be filled with broken stone and gravel, to make a hard road for the horses. Crossings from one track to the other were to be put in at the rate of eight in a mile.

The cost of transportation is reckoned in the following manner: Two horses being able to haul 20 tons on a level, and also on grades not exceeding 26 feet per mile, with additional horses for steeper inclines, and going at three miles per hour, would make the trip from Boston to Albany in four days, the distance being divided into ten stages of 20 miles each. We have then:

20 horses at 50 cts. a day each	$10.00
8 horses extra for steep grades	4.00
1 man, 4 days, at $1 a day	4.00
6 wagons at 75 cts. each a day	3.00
	$21.00

To the above there is added for profit to the carrier, and the hazard of going sometimes partly loaded, 50 per cent, making the total cost for 16 net tons $31.50 or $1.97 per net ton. "This estimate," says the report, "is intended to show the cost, exclusive of tolls, at which heavy articles paying the lowest rates can be carried, and of which it may be presumed there will be enough to employ the regular carriers. The rate of tolls would be subject to the discretion of the managers, to be so regulated as best to benefit the public and at the same time to secure the highest income. To do this the tolls should be fixed so low as to secure to the road the preference over all other means of conveyance. It is also well to charge less per ton for bulky and cheap articles than for those which

are more costly. On articles carried through from Boston to Albany or the reverse it would be only requisite, to secure the whole traffic for the railroad, that the freight should be as low as the rate together with insurance by water, as the greater expedition and certainty of conveyance by railway would give the preference to that mode. The common rate of freight by sloop navigation is from \$3 to \$4 a ton, but is sometimes as low as \$2.50. The usual rate of insurance is ¾ per cent. If we add to the estimate above of the cost of transportation \$1 a ton for tolls, we have \$2.97 a ton from Boston to Albany. More costly articles paying a higher insurance by sea would bear a higher rate of toll by railway. All articles carried to or from intermediate places could bear a much higher rate of toll than those which are carried from one extreme to the other because the accommodation to those places is greater."

With regard to the transportation of passengers, the report says, "A horse may go 12 or 13 miles a day, at the rate of 9 miles an hour, with a tractive force of 28 lbs., or 2½ tons, or a carriage of 20 passengers and baggage on a railroad. The cost would thus be

22 horses at 50 cts. each per day	\$11.00
2 men and 1 carriage	3 00
	\$14.00

Add to this, as in the case of freight, 50 per cent, and we have the cost of carrying 20 passengers \$21.00 or \$1.05 per passenger, to which we add for toll \$2.00, and we have the total \$3.05 for going from Boston to Albany in 22 hours" The report concludes that as coal is very dear in the United States while oats are cheap, horse power will be much cheaper than steam, unless it is important to move large loads of 50 or 100 tons at a rapid speed.

In estimating the amount of traffic to be expected, it is stated that the annual tonnage between Boston and Albany (in 1828) was 28,902, and that between the several counties along the line it is 102,848, while from Vermont and Connecticut comes 10,000 more. With regard to passengers, there were in 1828 six lines of stages, on all of which 18 coaches, besides extras, generally well loaded, running through from Boston to Albany and back, carrying an average of 50 passengers a day, both passages included. Of this number it was reckoned that 45 per day would travel on the railroad, while 30 more might be added for way passengers, making 75 in all. At a rate of half a cent per ton per mile for through freight, and two cents for local freight, and one cent per mile for passengers, the annual income thus becomes \$190,787. As the amount of traffic would certainly be increased by the improved mode of transport and by the decreased rates, it is considered in the report safe to augment the amount above to \$203,000. This was reckoned enough to pay the interest on the cost and the maintenance; and the prospect of an increase of population, wealth and business, was regarded as a sufficient reserved fund for paying off the principal of the debt.

The surveys for the Providence road were made by James Hayward, and embraced several routes. The most westerly started from the corner of Charles and Boylston streets, and ran through Roxbury, Dedham, Walpole, Wrentham and Pawtucket, to the end of the Blackstone Canal. The eastern route started near South Boston Bridge, and ran through

Dorchester, Milton, Canton, Sharon, Attleboro', by Sekonk Cove to India Bridge. Between these routes various other surveys were made, which, with numerous cross lines, admitted of a great number of combinations and furnished a very complete knowledge of the ground. The line selected as the best began at Front street (Harrison avenue) in Boston, and crossing Washington street, near South Boston Bridge, ran on the west side of the Neck to Wait's Mill, in Roxbury; or the same point was reached from the corner of Charles and Boylston streets, near the Common. From Wait's mill the line ran through Roxbury, the west part of Dorchester, the east part of Dedham, the middle of Walpole and Foxborough, a corner of Mansfield and Attleboro', and crossing Pawtucket River, near Central Falls, ran through the east part of Providence to India Point. The distance from Front street to India Point was 42 miles and 65 chains, the whole ascent 381 feet, the descent 378 feet, and the steepest grade 30 feet per mile. The estimated cost was $321,826 for a single track, and $629,134 for a double line. The number of tons of freight moved between Boston and Providence in 1827 was 27,190, and the number of passengers, carried by the "Citizens'" and "Commercial Line" of stages, 24,100. To provide for the interest on the cost of the road, and also for maintenance, an annual income of $24,000 was reckoned necessary, half of which would be raised by a toll of 50 cents on each passenger, without supposing any increase in the number.

In reply to the question, by whom should the roads be built, the Board considered that works of such magnitude, and on which the public accommodation so essentially depended, should be made under State control. They feared that a grant sufficiently broad to attract the necessary amount of private capital might prevent the interests of the public from being secured. They, therefore, recommended that these works should be undertaken on behalf of the State, money being raised by the sale of 4½ per cent. stocks running not less than 15 or 20 years.

While this report, which was laid before the Legislature in the winter of 1829, produced no very marked effect on that body, it threw a good deal of light upon the new mode of transport, and awakened equally public spirit and private enterprise. By the persistent and well-directed action of one of the ablest and most indefatigable friends of the railway, Nathan Hale, the public was, slowly but surely, made to see the vast importance of this invention. The success of the Rocket upon the Liverpool and Manchester Railway at just this time, gave the final illustration to his arguments, and the following year saw the charters given for the railroads from Boston to Lowell, to Providence and to Worcester. The early history of these roads is full of interesting detail, both from a commercial and an engineering point of view. Whenever that history shall be written, there will be brought before us a group of remarkable men—men whose names at this time are not very widely known, but who are, nevertheless, to be enrolled among our greatest public benefactors; men who were far-sighted, public-spirited and of exhaustless energy and resource; men who, with infinite faith in the future, felt their way along from small beginnings to a great end, and laid the foundations of that system of internal improvements by means of which Massachusetts has become a great and prosperous commonwealth.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

OCTOBER 15, 1884:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 8 P. M.

Vice-President L. Frederick Rice in the chair; twenty-six members and two visitors present.

The record of the last meeting was read and approved.

The amendments to the Constitution relating to dues proposed and adopted at the last meeting were again adopted.

The Committee on the Introduction of the Metric System presented a report.

On motion it was voted: That the report of the Committee be accepted and printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Mr. A. H. Howland read a paper entitled "The Metric System and Our Society." On motion of Mr. G. R. Hardy it was voted: That Mr. Howland be requested to present his paper to the Society; that it be printed with the transactions of the Society, and that he be granted the privilege of correction and revision.

On motion of Mr. Fitz Gerald it was voted: That the Secretary be authorized to cast one vote for Messrs. George H. Crafts and Marshall M. Tidd, candidates for membership in the Society. As the result of this ballot the above-named candidates were declared elected members.

Messrs. Earle H. Gowing, Lawson B. Bidwell, and Henry A. Phillips were proposed for membership.

On motion of Mr. F. P. Stearns it was voted: That the Treasurer be authorized to pay four dollars of the membership fee due from George H. Crafts, who was formerly a member of the Society and had withdrawn in good standing.

On motion of Mr. Manley it was voted: That the Secretary be authorized to issue a revised Constitution and By-Laws and list of Members.

Mr. G. R. Hardy read a paper on "Improved Railway Signal Apparatus as Adopted by the Boston & Albany Railroad."

On motion it was voted: That a vote of thanks be extended to the General Superintendent of the Boston & Albany Railroad for the courtesies extended to the members of the Boston Society of Civil Engineers who attended the excursion to Riverside, October 15, 1884.

That a vote of thanks be extended to Mr. Charles R. Johnson, Signal Engineer of the Union Switch and Signal Company, for the kindness and attention shown the members of this Society at the Riverside Signal Station October 15, 1884.

[*Adjourned.*] H. L. EATON, Secretary.

EXCURSION OF THE SOCIETY TO THE RIVERSIDE SIGNAL STATION, BOSTON & ALBANY RAILROAD, OCTOBER 15, 1884.

On the afternoon of October 15, 1884, about thirty members of the Society visited the Riverside Signal Tower on the line of the Boston & Albany Railroad. By the courtesy of the General Superintendent of the road a special car was provided on the 4:25 P. M. train. Arriving at Riverside the party was taken to the Signal Tower and shown the apparatus designed and applied by the Union Switch & Signal Company to facilitate the movement and control of switches and signals. At the station the four main tracks are reduced to two, and the Newton Lower Falls Branch makes a junction with the main track. The members of the party were greatly indebted to Mr. G. R. Hardy, Assistant Chief Engineer of the Boston & Albany Railroad, for his careful explanation of the apparatus and for the arrangement of the details of the excursion.

The party was also indebted to Mr. Charles R. Johnson, Signal Engineer, Union Switch & Signal Company.

H. L. EATON, Secretary.

NOVEMBER 19, 1884:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P.M.

President George L. Vose in the chair, eighteen members and two visitors present.

The record of the last meeting was read and approved.

On motion of the Secretary it was voted: That an appropriation of thirty dollars be made for renewing the Society's subscription to the usual periodicals for the year 1885.

On motion of Mr. H. Manley it was voted: That the question of furnishing the proceedings of the Society to the State Library be referred to the Government with full powers.

Mr. James W. Sewall was proposed for membership, recommended by Messrs. G. L. Vose and A. E. Burton.

Messrs. Lawson B. Bidwell, Henry A. Phillips and Earle H. Gowing were elected members of the Society.

Mr. W. H. Bradley addressed the Society on the "Drainage of the Everglades."

Mr. J. F. Flagg, M. A. S. C. E., was introduced by the President and described a cantilever bridge of seventy feet span, built by a Mexican laborer from his own designs and entirely of native woods and vines.

President G. L. Vose read a paper on the "Early History of Transportation in Massachusetts."

H. L. EATON, Secretary.

[*Adjourned.*]

ENGINEERS' CLUB OF ST. LOUIS.

NOVEMBER 19, 1884:—The Club met in the parlors of the Mercantile Club-House, President Woodward in the chair and twenty-one members present. The minutes of last meeting were read and approved.

The Committee on Revision of Constitution reported an entire new Constitution to be adopted in place of the old one, which was framed for the Club when it consisted of but a few members, sixteen years ago. The report was accepted and the Committee discharged.

Moved, That the draft of the Constitution offered be adopted as the Constitution of the club, to the exclusion of the old one.

This resolution lies over till next meeting.

Mr. McMath offered an amendment to the new Constitution, making the annual meeting come on the first Wednesday after the first day of January of each year, instead of the first Wednesday in December.

Moved that the draft of the new Constitution as submitted by the Committee be printed and sent to all members before the next meeting. Mr. Engler was made a committee of one to attend to this.

Moved that at next meeting the vote be taken on the Constitution article by article seriatim.

Moved that the Club meet again on Wednesday evening, November 26, to consider the new Constitution.

Mr. White made an informal report from the Committee on Smoke Prevention. The report was accepted and the Committee discharged.

The following gentlemen were unanimously elected to membership:

E. D. Libby, J. E. Savage, Gerald Bagnall, W. S. Mitchell, C. C. Brown, and H. S. Pritchett.

The following names were proposed for membership:

J. L. Stubblefield, C. P. Mitchell, J. L. Duffy, and C. D. Lamb, by C. V. Mesereau and J. B. Johnson; Thos. J. Caldwell by Thos. D. Miller and Geo. Burnett, Jr.; T. T. Johnston by H. W. Baker and C. V. Mesereau, and Chas. Varrellmann by Thos. H. Macklind and Wm. Wise.

Moved that a committee of three be appointed to take under advisement the arrangements for the annual meeting and report at next meeting. Messrs. Macklind, Mersereau and Pond were appointed.

A general discussion followed on the paper read at the previous meeting on the "Creep-

ing of Rails on the St. Louis Bridge," but no new evidence was given or theories advanced.

Mr. Johnson presented a paper on the "Strength of Solid Metallic Rollers to Resist Crushing," which was read by title and ordered printed in the JOURNAL.

[*Adjourned.*] J. B. JOHNSON, Secretary.

NOVEMBER 26, 1884:—The Club met at the rooms of the Mercantile Club, President Woodward in the chair and twenty-one members present. The minutes were read and approved.

The Committee on Arrangements for the annual meeting reported in favor of a banquet, offering two bills of fare, one at $2.50 and the other at $4.00 a plate. They said an excursion to New Orleans had been talked of, and perhaps could be arranged. The report was accepted and the Committee discharged. On motion the report was then laid on the table.

The following gentlemen were unanimously elected: J. L. Stubblefield, C. P. Mitchell, J. L. Duffy, C. D. Lamb, Thos. J. Caldwell, T. T. Johnston, and Chas. Varrellmann.

W. L. Breckinridge was nominated for membership by Thos. D. Miller, E. A. Engler and C. M. Woodward.

The adoption of the new Constitution was taken up in Committee of the Whole and adopted article by article.

Moved, That the officers of the Club be instructed to take such steps as may be necessary to secure the legal recognition of the new Constitution.

Moved, That Mr. Engler be appointed a Committee of one to see to the printing of the Constitution and a list of the Members with their addresses.

Moved, That a committee of five be appointed to nominate officers for the next year.

The following were appointed by the Club: F. H. Pond, T. J. Whitman, Geo. Burnett, E. A. Engler, and J. B. Johnson.

The following resolution was offered by Robt Moore, and unanimously adopted:

To the Honorable Speaker and House of Representatives:

Your petitioners, the Engineers' Club of St. Louis, Mo., respectfully represent to your Honorable Body that the present duty of twenty-five per cent. upon scientific books imported into this country is a serious obstacle in the way of their professional studies, which they earnestly ask you to remove. They ask this with the greater confidence from the fact that the sale for such books is so limited that, with very rare exceptions, they are not and cannot be profitably republished in this country, so that the duty in question promotes no private interest, but is simply a tax upon the means of knowledge by which a small amount of money is collected for which the Government has now no need.

[*Adjourned.*] J. B. JOHNSON, Secretary.

ANNUAL MEETING.

DECEMBER 3, 1884:—The Club met at the Mercantile Club House, President Woodward in the chair and thirty-two members present.

The minutes of the last meeting were read and approved.

The report of the Treasurer was read and accepted.

The following report of the Secretary was read and accepted:—

Gentlemen: Your Secretary would respectfully submit the following report of the growth and work of the Club for the past year. There have been seventeen meetings of the Club, at thirteen of which regularly announced papers were read. The average attendance at these meetings has been twenty-three members. Eighteen papers have been presented, all but one of which have been or are to be published in the ASSOCIATED JOURNAL.

The following members have contributed papers: Mr. H. C. Moore, Mr. Gayler, Mr. Sobolewski, Mr. Woodward, Mr. McMath, Mr. Robert Moore, Mr. O. Chanute (not a member), Mr. Humphreys, Mr. Miller, Mr. J. W. Hill, Mr. Adams, Mr. Johnson, Mr. Constable and Mr. Nipher.

There have been forty-nine new members received into the Club, and six names dropped from the rolls. The total membership is now one hundred and six.

The meetings have been held at four localities during the year, as follows: Four at the office of the City Water Commissioner, six at the Mercantile Library, two at Washington University, and five at the Mercantile Club Rooms. The Mercantile Library facilities were obtained in consideration of the Club's taking forty membership tickets at five dollars each per annum (being the regular price of such tickets), the Library to furnish the room in which to hold meetings without any charge whatever. These forty tickets were all placed with the Club members at the rate of four dollars each, the other dollar being the amount by which the annual dues for resident members were expected to exceed the cost of the JOURNAL.

The offer of the rooms in the Mercantile Club House for holding our meetings came unsolicited. This generous offer was gratefully accepted and we are informed the engagement is to hold good until further notice. It would not be advisable, however, to break the connection with the Mercantile Library, for the more intimate our relations there, the more influence we can have in the matter of selection and purchase of Engineering Literature. Besides, when their new building is erected, they promise to provide permanent quarters for the St. Louis Engineers' Club.

The Club has been the recipient of various publications and donations. It regularly receives the proceedings of the American Society of Civil Engineers, and those of the Philadelphia and Pittsburgh clubs. The most notable donations in the past year have been the complete proceedings of the American Society of Civil Engineers, which have been bound in twelve volumes, and the report of the New Boston Water Supply from Sudbury River.

A new constitution has been adopted, more in accordance with the present need of the Club than that which has served for the past sixteen years.

The Club is now in excellent working condition and there seems no reason why it should not so continue. The success of the past year is due to a generally awakened interest in the matter, which can be largely traced to the work of the Committee on Programme, who provided for so valuable a series of papers for the meetings. It is perhaps not too much to say that no local engineers' organization in this country has done better work in the past year than our little Club.

The Association to which we belong is in a flourishing condition. One additional society has joined it in the past year, and two are contemplating so doing. It would seem that this Association looks toward a general unification of engineering interests in the United States at least, wherein the local interests shall not be sacrificed. It is very desirable that all reputable engineers whose interests centre in St. Louis, and as many others as may be drawn to us, should unite with this Club in its efforts at self-improvement, mutual instruction, and the general unification and elevation of the profession. I believe we might as well number two hundred members as one hundred. It is to this larger work that we should now devote our energies.

As to the character of our meetings, many members have expressed a desire that they might be somewhat more informal and sociable. I believe this end could be attained by leaving a portion of each meeting to the presentation of various matters of interest which may arise in the several special fields of practice in which members are engaged, thus furnishing an opportunity for some informal discussion, queries, suggestions, etc. There is no practical engineer who does not meet with many such items in the course of a year which could profitably be presented to the Club. If time for this cannot be found in any other way, it may be found advisable to limit the time for the reading of the papers, and if the article is long, let only portions or an abstract be given, inasmuch as the article will come to each member in printed form, when he can peruse it at pleasure. At least some scheme should be adopted by which members who attend regularly may obtain at least a speaking acquaintance with each other in the course of a year. Respectfully submitted, J. B. JOHNSON.

The name of Mr. Claude Freeman was dropped from the rolls in accordance with the recommendation of the Treasurer. The Secretary was instructed to correspond with Mr. O. A. Haines and find his wishes in regard to retaining his membership.

Prof. W. B. Potter reported for the Committee on Library. Many engineering books and periodicals had been purchased by the Mercantile Library, on their suggestion, and they were expecting to prepare a special catalogue of engineering books. The report was accepted.

The Committee on Programme for the next six months reported through their Chair-

man, Prof. C. M. Woodward. The report was accepted and the Committee discharged, the duty of executing the scheme devolving upon the incoming Executive Committee. The report is as follows:

St. Louis, December 3, 1884.

Mr. President: Your Committee on Programme for the coming season beg leave to submit the following report :

Your Committee are aware that they have an important duty to perform. The arrangement of a programme includes the fixing of the dates on which the Club shall regularly meet during the next six months ; the acceptance and often the assignment of subjects ; and above all the securing of the active co-operation of those members of the Club able to present valuable papers.

They are happy to state that they have found no lack of excellent material, and that, as will be seen below, several papers will be held in reserve.

The programme we submit is as follows :

December 17, "Earlier Floods in the Mississippi," by J. A. Ockerson, U. S. Assistant Engineer.

January 7, "Economy in Gas Engines," by J. Sobolewski, Inspector St. Louis Gas Co.; and "Protection against Fire and Means of Extinguishing the Same," by C. T. Aubin, Engr. to Board of Underwriters.

January 21, "The Use of Compressed Air," by C. Shaler Smith, Engr. Illinois & St. Louis Bridge Co. ; and "An Improved Crane," by Frederick Shickle, of Shickle, Harrison & Co.

February 4, "Eliminations of Errors in Field Work," by Wm. Bouton, City Surveyor; and "Mill Creek Sewer," by Wm. Wise, Chief Asst. Engr. Sewer Dept.

February 18, "Street Pavements," by Thomas H. Macklind, Chief Asst. Engr. Street Dept. and "Improvement in Switches," by Hubert Taussig, Engr. in charge S. L. Depot Yds.

March 4, "Experiments in Hydraulics," by Henry Flad, Pres. Board of Public Works, and "Treatment of Wood for Street Pavements," by T. D. Miller, City Gas Inspector, and T. J. Caldwell, Special Expert on Wood Preserving.

March 18, "Pile Driving and Related Work," by C. V. Mersereau, U. S. Asst. Engineer, and "The Use of Diagrams of Crank Effort in Designing," by W. H. Alderdice, Asst. Engineer U. S Navy.

April 1, "Amsler Integrators," by M. L. Holman, Chief Asst. Engr Water Dept., and "Construction in wood and Iron," by K. Tully, Architect and U. S. Asst. Engr.

April 15, "Steamboat Shafts," by H. W. Baker, U. S. Asst. Engineer, and "The Efficiency of a Pair of Holtz Machines, one Acting as Generator, the other as Motor," by F. E. Nipher, Prof. of Physics, Washington University.

April 29, "The Utilization of Fuel by the Generative System," by Wm. B. Potter, Prof. of Mining and Metallurgy, and "Dynamometers," by Chas. F. White, Supt. of Shops, Manual Training School.

May 13, "Pumping Engines for Water Works," by Frank H. Pond, of Pond Engineering Co., and "The Theory of Car Starters," by J. B. Johnson, Prof. Civ. Eng., Wash. Univ.

May 27, "The Theory of Ammonia Refrigerating Processes," and "Report of the Committee on Smoke Prevention," by C. M. Woodward, Dean of Polytechnic School, Washington Univ.

Several papers have been half promised and are held in reserve for cases of unavoidable failure, and for additional meetings should the Club see fit to continue semi-monthly meetings into the summer. Your Committee recommend that this programme, when adopted, be printed as a circular and distributed among the members of the Club and other interested persons.

It will be noticed that all names on the above programme appear without titles.* They suggest, however, that on the circular it may be best to insert appropriate titles.

Respectfully submitted,

C. M. Woodward,
Robt. McMath, } Committee.
J. A. Ockerson

* The titles inserted by the Secretary.

The Committee on Nominations for Officers for the Club for the ensuing year reported as follows :

Gentlemen : Your Committee appointed at the last meeting to suggest names of candidates for office for the ensuing year beg leave to submit the following report :

They recommend for

President,	Robert Moore,	Ex. Committee.
Vice-President,	Robt. E. McMath,	
Secretary,	Thos. D. Miller,	
Director (1),	C. M. Woodward,	
Director (2),	Thos. J. Whitman,	
Treasurer,	M. L. Holman,	
Librarian,	J. B. Johnson.	

Frank H. Pond, Thos. J. Whitman,
E. A. Engler, Geo. Burnet,
J. B. Johnson, *Committee.*

The report was accepted and the Committee was discharged.

The following additional nominations were made :

For President, - C. M. Woodward.

For Directors, Theo. Allen, Howard Constable, Frank H. Pond.

All the above nominations to be sent to the members and the election to be by letter ballot.

The following nominations for membership were made: A. P. Man, by Geo. Burnett and M. L. Holman; and E. L. Foote, by H. A. Wheeler and E. A. Engler.

Moved by M. L. Holman, that it is the sentiment of the Club that it is desirable to limit the reading time of any paper to about thirty minutes. Carried.

The object of this resolution is not to limit the length of the paper, which will be printed in full in the Journal, but, if necessary to present only an abstract of the paper, or such portion as can profitably be presented orally, and so obtain more time for the discussion and for the introduction of other subjects.

Robt. Moore then read a paper on "Sewerage and House Drainage in St. Louis," treating the subject historically.

The thanks of the Club were tendered to Mr. Moore for his valuable paper, most of the data for which had been obtained from unpublished sources.

After the reading of the paper Mr. Whitman gave an account of the successful lowering of a thirty-six inch water-main by about seven feet without cutting off the supply or diminishing the pressure. The lowering was made necessary by a change of street grade on Twentieth street, from Benton Street to Maiden Lane. The lowering was made in successive stages of about a foot at a time. The last stage was 19 inches, and the lowering was accomplished in about an hour and and a half. A stank of about four feet in length was left at each bell, the rest of the trench being dug 18 inches deep. When all was ready the stanks were removed gradually and the pipe settled down uniformly. The lowering was necessary on account of change of elevation of street grade. *No pipes were broken or cracked and no leaks other than a slight wetting of the joints occurred.* The adjustment for length was made by forcing the pipe into a horizontal reversed curve as the pipe settled, and straightening it out again when the pipe reached the desired grade. The total length was about the same in first and last positions, the former being convex upward and the latter convex downward by about the same amount. After some further discussion the Club adjourned.

J. B. Johnson, Secretary.

WESTERN SOCIETY OF ENGINEERS.

November 18, 1884:—The 197th meeting was held at four p. m., President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

(Tuesday, Nov. 4, no quorum was present, and no meeting was held.)

Applications for membership were presented as follows:

John Davis Arey, Civil Engineer. Rock Falls. Ill., indorsed by Messrs. Kirby, Morehouse and Wright.

Charles P. Matlack, City Engineer, San Antonio, Texas, indorsed by Messrs. Franklin, Morehouse and Cregier.

Letters were read by the Secretary from Messrs. Bridges, Draper and Dean, all in favor of remaining in the Association of Engineering Societies.

It was voted that the President and Secretary select and purchase suitable frames or albums for the reception of photograph likenesses furnished by members.

A discussion was had on the subject of Compressed Air, the Cable System, and other methods of propelling railway cars.

[*Adjourned.*] L. P. Morehouse, Secretary.

December 2, 1884:—The 198th meeting was held at 4 p. m. President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

The Secretary reported a gift of valuable books and pamphlets from Mr. E. S. Chesbrough, also the receipt of a photograph likeness from Mr. Samuel McElroy.

The President having to leave, Vice-President Randolph took the chair.

In accordance with a resolution adopted October 7 last, written nominations were presented for officers to be elected at the next annual meeting, and the following persons having received the two highest number of votes for the respective offices were declared the nominees:

(The name of the person receiving the highest number of votes is placed first.)

For President.

Benezette Williams. D. C. Cregier.

For First Vice-President.

Octave Chanute. Isham Randolph.

For Second Vice-President.

S. McElroy. { F. Slataper. A. W. Wright.

For Secretary.

L. P. Morehouse. A. W. Wright.

For Treasurer.

Charles Fitz Simons.

For Librarian.

G. A. M. Liljencrantz. W. S. MacHarg.

For Trustee.

A. W. Wright. O. B. Green.

After the nominations were declared Mr. Williams stated that he desired to withdraw his name as a candidate. The Secretary was instructed to note this statement in the minutes of the meeting.

A letter ballot on the proposed amendments to Constitution and By-Laws was taken, and all the amendments as proposed at the meeting October 7, 1884, were adopted.

Mr. Wright presented the following, which was seconded by Mr. Artingstall:

Whereas, This Society voted to withdraw from the Association of Engineering Societies, and

Whereas, The views of many who voted in favor of withdrawal have been changed, and it is believed that the majority of the members of this Society are now in favor of rejoining the said Association, as evidenced by written and verbal expressions of views, be it

Resolved, That the Secretary be authorized to make the necessary arrangements for this Society to continue a member of the said Association.

On motion of Gen. Fitz Simons it was voted that action on the foregoing be postponed to the next meeting. L. P. Morehouse, Secretary.

[*Adjourned.*]

December 16, 1884:—The 199th meeting was held at 4 p. m. Vice-President Wright in the chair.

The minutes of the preceding meeting were read and approved.

The Committee on Railroads and Transportation reported two papers; one for this meeting by Mr. A. M. Wright, and one for the second meeting in January, "What Civilization Owes to the Architect and the Civil Engineer," by Mr. G. R. Bramhall.

The motion of Mr. Wright, presented at the last meeting, to the effect that the Society

retain its connection with the Association of Engineering Societies, being called up, the Secretary read a letter from Mr. W. Howard White, protesting against withdrawal, and, after discussion, the motion of Mr. Wright as printed in the proceedings of the last meeting was adopted.

The following resolution was also adopted:

Resolved, That the Secretary is hereby instructed to revise the subscription list for copies of the JOURNAL and omit therefrom the names of members whose dues are delinquent for a period of six months.

Mr. Wright read the paper for the evening, "The Origin of the Word Tramway."

It was voted that the paper be printed in the *Journal* and should be made a subject of discussion at the next meeting. L. P. MOREHOUSE, Secretary.

[*Adjourned.*]

CIVIL ENGINEERS' CLUB OF CLEVELAND.

OCTOBER 14, 1884:—Regular meeting held, President Holloway in the chair.

Minutes of previous meeting read and approved.

In the absence of the Secretary the Corresponding Secretary was requested to act in his place.

The following resolution was offered by Mr. Rawson and carried:

Resolved, That the Treasurer be and he is hereby authorized, to pay to the Association of Engineering Societies for the purposes of joint publication an amount not to exceed $3.00 per member based upon the present mailing list.

The following resolution was offered by Mr. Whitelaw and carried:

Resolved, That, as we have all received the sad intelligence of the death of Mr. J. D. Crehore, a member of this Club, a committee of three be appointed to express in fitting terms the feelings of the Club.

The chair appointed Messrs. J. N. Stockwell, J. Whitelaw, W. R. Warner as such committee.

Mr. Alex. E. Brown then read a paper describing the Brown Automatic Blast Furnace Filler, illustrating his description with neat and suitable drawings.

The Filler consists of an inclined iron bridge running from the stock house floor to the furnace top, on which is hoisted a skip, dumping automatically at the top. The whole arrangement does away with the vertical hoist and all labor at the top of the furnace. The numerous clever mechanical details in connection with the Filler were explained by Mr. Brown, especially the automatic steam valve, the correct position of the material in the hopper, and its correct angle of incline, depending on the size of the furnace and kind of ore, as well as an automatic register of the height of the stock every time the bell was lowered.

An interesting discussion followed, in which it was shown that though many of the details were new and the arrangements were most carefully worked out by Mr. Brown, the general idea had been used abroad for some years.

After a vote of thanks to Mr. Brown for his interesting paper the meeting adjourned.

A. MORDECAI, Sec'y pro tem.

NOVEMBER 11, 1884:—Regular meeting held, President Holloway in the chair. Minutes of last meeting read and approved.

The following letter from Prof. Eisenmann was read: "Permit me herewith to tender my resignation as Chairman of the Committees on Programme and Architecture. Since my appointment my professional work has prevented me from devoting the time to the work of the committees which the Club has the right to expect, and which my own sense of duty demands."

On motion Prof. Eisenmann's resignation was accepted, and it was left to the Programme Committee to select a new chairman.

The Committee on Resolutions of Respect to the Memory of Mr. Crehore, appointed at a previous meeting, reported as follows:

Resolutions of Respect to the Memory of John D. Crehore, Member of the Civil Engineers' Club of Cleveland.

Whereas, The members of the Civil Engineers' Club of Cleveland have heard with profound sorrow and regret of the death of Mr. John D. Crehore; therefore be it

Resolved, That in the death of Mr. Crehore the engineering science of the country

has sustained an irreparable loss, inasmuch as the great work of his life, which was so nearly finished, no one lives to finish in the masterly manner in which it has been thus far developed.

Resolved, That the Civil Engineers' Club of Cleveland earnestly recommend the early publication of the work on which he was so long engaged, since it will so greatly enrich the science of which it treats, and serve as a lasting, though unfinished, memorial of his talents and his worth.

Resolved, That while he held a position among the highest of our profession, he will be remembered and admired on account of his great personal worth and purity of character.

Resolved, That the sympathy of the Engineers' Club be tendered to the wife and family of the deceased, as a token of the high regard and esteem which they accord to his cherished memory.

JOHN N. STOCKWELL,
JOHN WHITELAW,
W. R. WARNER,
} Committee.

Prof. Stockwell, in presenting the resolutions, delivered the following brief eulogy and biographical sketch of Mr. Crehore's life.

BIOGRAPHICAL NOTICE OF MR. JOHN D. CREHORE.

BY J. N. STOCKWELL.

It is no common event we are called upon to commemorate. Death comes with an impartial tread into the hovels of the poor and the mansions of the rich, and is a messenger too well known to us all. But it is seldom that he attains a mark that is so conspicuous—so far above the average of humanity in intellectual development and scientific culture In the death of Mr. Crehore the community has lost an estimable citizen the Club an efficient and active member, and Engineering Science one of its ablest and most prominent cultivators. It is, therefore, believed that a short biographical notice of his life and labors may be of interest to those now present.

Mr. John D. Crehore was born Nov. 22, 1826, at Walpole, New Hampshire. His father died when the son was only four years old; and the financial circumstances of the family were such that his mother was wholly unable to contribute anything toward defraying the expenses of his education; and he was therefore obliged to depend wholly on his own resources. In this he was successful, and he graduated with honor from Dartmouth College in 1854. In the year 1856 he studied at the Lawrence Scientific School during the spring and fall, until October 9, when he accepted an invitation to teach Mathematics and the Natural Sciences in the Central High School of this city. He was connected with the High School during two years, and at the end of that time he entered the Law Office of Williamson and Riddle, not for the purpose of becoming an advocate, but because he believed that a certain amount of legal knowledge would be found useful in almost every profession. After spending nearly a year as a law student he resumed his studies at the Lawrence Scientific School in October, 1859. In March, 1860, he entered as a Resident Graduate, but he was soon after called away by sickness at home.

In August, 1860, he received an invitation to teach in the Washington University at St. Louis, and while there he had the pleasure and advantage of assisting Professor Chauvenet in some of the calculations for his great work on Spherical and Practical Astronomy. This experience

must have been of incalculable advantage to him, since the work is a model of elegance and precision, unsurpassed by any similar production in the English language. He afterward assisted in reading the proof-sheets, and also prepared the Index to that work in the summer of 1862.

In December, 1862, he married Miss Lucy Williams, the third daughter of Wm. Williams, Esq., of this city; but he retained his position in the Washington University until June, 1863. He then spent some time in seeking for a position as engineer in railroad or other machine shops; but, as nothing favorable offered, he went into partnership with Charles Bradburn and Grant F. Williams, both now deceased, as wholesale grocers, on Water street in this city. He continued in the wholesale business for only a few years, when the partnership was dissolved on account of the failing health of Mr. Williams. It had not, however, been a financial success, and he then started in for himself in an office in the basement of the Savings Bank Building, as a surveyor and civil engineer. He subsequently removed to one of the upper stories of the Cushing Block and continued the business until near the middle of 1873, when he went to St. Louis again (that being about the time the great bridge across the Mississippi River was being built) for the purpose of getting better established in his particular line of business, bridge building. He remained in St. Louis till the beginning of 1874, when he returned to Cleveland, and has remained here ever since.

It was about this time that he conceived the design of uniting in one great work the whole of the science of bridge building, and he at once began to collect and digest the materials which have been so fully elaborated and incorporated in his posthumous work entitled "Mechanics of the Girder." Under this comprehensive title he has given an elaborate discussion of the various forms of trusses in common use; and the theoretical and practical bridge builder only can fully comprehend just how much such a discussion implies. Every arch and beam, and brace and bolt must be of a definite size and shape in order to best fulfill the condition of maximum strength and minimum weight. For in this utilitarian age it becomes a matter of importance to so utilize the materials that each part shall possess just the requisite weight and strength to perform the functions due to its position in the structure. And it is no doubt from a want of the proper symmetry of form and weight, rather than from a lack of material, that a bridge breaks down but doesn't wear out. In fact a perfect bridge must possess all the properties of the Deacon's masterpiece, as embodied in the "Wonderful One-Hoss Shay"

Now the "Mechanics of the Girder" very fully explains the theory by which the forces acting upon a bridge are distributed throughout the structure, and illustrates by copious examples the process by which the size and weight of any part of a bridge of any given form may be accurately calculated in order that the structure may sustain given weight by the use of the minimum amount of materials in its construction.

Our author has very fully developed the theory of twelve different kinds of girders, and has prepared very elaborate tables of analytical formulæ by means of which the less skillful mathematician can make the application to any case that may come up for consideration. It was,

however, a source of regret that he was unable to complete certain numerical tables illustrative of the different kinds of girders of which he has given the theory; but this defect will, I think, be supplied from other sources before the publication of the work. Mr. Crehore has devoted the greater part of his time during the past ten years to the preparation of this work; and the amount of calculation which it entailed upon him was simply immense. Indeed, it was too great for any one who is not possessed of extraordinary powers of physical and mental endurance, and exhausted Nature gave premonitory warnings in the form of severe headaches as long ago as 1880. By careful management he gradually recovered from these slight indispositions, and was able to continue his investigations about two years longer. Then from September, 1882, till May, 1883, he was obliged to desist from all intellectual labor, and during the last year of his life he had frequent interruptions of short duration resulting from the same cause, although his general health seemed better than it had been for some years previously. Our colleague was a very excellent mathematician, although his labors were confined more to the field of practical than speculative science. His solution of the equation of the fourth degree is unsurpassed in elegance by that of any of the great masters of science who have labored in this interesting field of inquiry. It had always been the custom in the solution of equations of the third and fourth degrees, to make the second term disappear as a preliminary part of the operation; but Mr. Crehore boldly attacked it without this preliminary simplification and obtained a solution quite as simple and elegant as had been obtained by other methods.

No description of Mr. Crehore's intellectual character could be regarded as complete that omitted one predominant trait which prevaded all his opinions and lay deeply rooted in the very foundations of his nature. I mean that deep love of truth and loathing of all false assumption, which may be said to bear the same relation to honesty that honesty bears to what is called "worldly policy." There were few things which his modest and tolerant spirit could be said to hate; but he did hate sham, humbug and charlatanism with all the energies of his soul. He never claimed honor, rank, or position for himself, although he hastened to accord all these to others far less worthy than he; but he was restive at the sight of scientific rewards unworthily bestowed; and his sterling patriotism and sense of justice were outraged when he saw the holy wreaths of Fame bestowed upon those who were unworthy of such honors.

Our colleague had a kindly, gentle nature, and an affectionate regard for all around him. He made his own opportunities to help and cheer others, instead of waiting for them. Was a friend successful, he rejoiced with a cordiality that made him twice happy; in sorrow, he mourned with him, and with a sympathy that half lifted off the burden. As a friend I knew Crehore well, and can bear witness to the loyalty and gentleness of his nature. With a gayety never bordering on excess, a sympathy never exhausted, a kindly tact never forgotten, he was a companion such as we rarely meet.

Early in September of this year he visited Philadelphia in order to

attend the meeting of the American Association for the Advancement of Science, of which he had long been a member. Some of us had frequent opportunities of meeting him there; and I am sure that no one would then have expected that his lamp of life was so nearly burned out.

"Oh, had it been told you then
To mark whose lamp was dim,
From out those ranks of active men
Would you have singled him?"

While in Philadelphia he attended the excursion to the coal regions of Pennsylvania, and seemed to enjoy the trip with all the vim of one to whom fatigue was an utter stranger. Indeed the whole time there was a continued round of enjoyment, and he returned home after a ten days' absence feeling well repaid for the time and expense by the recreation it afforded.

He had, however, been home only a few days when his old-time trouble returned; but, instead of remaining as neuralgia of the head, as heretofore, it took a new departure and became neuralgia of the bowels. And from the effects of this painful disorder he rapidly declined in physical strength, although his heroic spirit gave no intimation that he was aware that Death would so soon gain the victory. Indeed his friends fully expected his recovery until within about two days of his death; but he died suddenly in the evening of October 7, and before many of his intimate friends were informed of his sickness. No lingering disease wasted his manly powers, nor was his active mind long fettered in the dungeon of an exhausted body. His brain was full of large ideas, his heart teeming with kindly affections, when "God's finger touched him and he slept."

Prof. W. B. Wood read a paper entitled "The Water Supply of Cleveland Chemically Considered," which was followed by an extensive and interesting discussion.

The members of the Committee on Joint Publication presented the action of the Board of Managers of the Association of Engineering Societies at its late meeting in New York, discountenancing the publication in other technical journals of matter read before the Club before such matter had been first published in the journal of the Association, such restriction not to apply to the publication in whole or in part in the daily press, and asked what action this Club would take in the matter.

On motion of Mr. Swasey, the matter was referred to a committee to be appointed by the Chair.

On motion of Mr. Richardson, the question was made to apply only to future papers, leaving the matter of the publication of all previous papers to the discretion of their authors.

[*Adjourned.*] M. W. Kingsley, Recording Secretary.

ENGINEERS' CLUB OF MINNESOTA.

November 14, 1884:—The Club was called to order by the President, eleven members being present.

The records of the last three meetings were read and approved.

Mr. Cooley, Manager for the Association of Engineering Societies for the Club, made a report of the doings of the Board of Managers at their last meeting, which report was received and placed on file.

It was voted to pay the first assessment of one dollar, as made by the Board of Managers of the Association of Engineering Societies.

Messrs. Abbott, Cooley and Angst were appointed a committee on procuring permanent quarters for the Club.

An assessment of six dollars per member was ordered.

Messrs. Frank Plummer and A. C. Libby were elected members of the Club.

The following were proposed for membership: W. F. Carr, by Wm. A. Pike and Wm. de la Barre; Edward Barrington, by W. W. Rich and Geo. W. Cooley; Wm. Brook by Wm. de la Barre and Geo. W. Cooley.

After an informal talk on the construction of the Canadian Pacific Railway by Mr Abbott and general discussion of the same, the Club adjourned.

WM. A. PIKE, Secretary

DECEMBER 12, 1884:—The Club met in the new room, No. 10 Vanderburgh Block, selected by the committee appointed at the last meeting, and was called to order by the President, with fourteen members present.

The minutes of the last meeting were read and approved.

The Committee on Rooms reported what they had done and the committee was discharged, with thanks for the prompt aud satisfactory performance of their duty, and their action was ratified by the Club.

Messrs. W. F. Caw, Edward Barrington and Wm. Brooks were elected members of the Club.

Mr. John T. Baker was proposed for membership by Wm. De la Barre and Andrew Rinker.

Voted to publish the transactions of the Club in the JOURNAL.

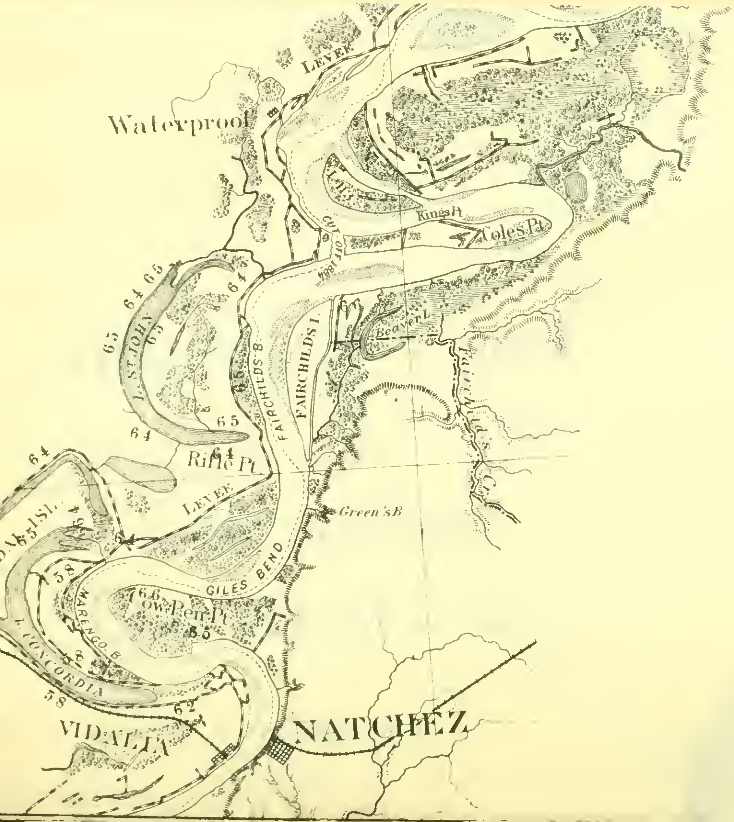
Mr. Abbott then read the paper of the evening on "The Rapid Construction of the Canadian Pacific Railroad," which was generally discussed, many questions as to details of cost, etc., being asked.

Voted to publish Mr. Abbott's paper in the JOURNAL of the Association.

Arrangements were made by which certain periodicals taken by members of the Club should be placed in the club-room for general use. WM. A. PIKE, Secretary.

[*Adjourned.*]

Map of
OLD RIVER LAKES
Along the
LOWER MISSISSIPPI.
SCALE
0 1 2 3 4 5 6 7 8 9 10 MILES
J. A. OCKERSON, C. E.
Omega
Milliken's Bend
MILLIKENS BEND
Walnut Bayou
Eagle Lake
Steele's Bayou
Cypress R.
YAZOO RIVER
Walnut Hill
VICKSBURG
Delta
Warrenton
Big Bayou
DAVIS ISL.
PALMYRA
NEWTOWN BEND
Pt. Pleasant
Lake St. Joseph
Thrashers Pt.
HARD TIMES
Coffee's Pt.
Big Black R.
Grand Gulf
PORT GIBSON
Bayou Pierre
L. Brae
St. JOSEPH
LEVEE
Rodney
Waterproof
Coles Pt.
Kings Pt.
FAIRCHILDS I.
Rifle Pt.
Giles Bend
Green s.B.
NATCHEZ
VIDALIA


Waterproof
LEVEE
L. 113
Kings Pt.
Coles Pt.
CUT OFF 1884
Beaver L.
FAIRCHILDS I.
FAIRCHILDS B.
Fairchild's Cr.
L. ST JOHN
Rifle Pt.
LEVEE
Green's B
GILES BEND
Cow Pen Pt.
MARENGO B.
L. CONCORDIA
VIDALIA
NATCHEZ

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE EARLIER FLOODS OF THE LOWER MISSISSIPPI.

By J. A. Ockerson, Member of the Engineers' Club of St. Louis.

[Read December 17, 1884.]

The disastrous floods of late years in the Ohio and Mississippi Rivers have called out a great deal of discussion as to the relative heights of the floods when compared with those occurring before the valleys were settled. These discussions have indeed been so elaborate that it would seem as though the subject was nearly exhausted. New facts have, however, recently come to light concerning the old-time floods, which it is thought will justify this slight addition to the literature of the subject.

In the absence of any authentic records of the earlier floods, except, perhaps, Indian traditions and some general statements of the "oldest inhabitant," many have come to the conclusion that great floods, like those of the past few years, never occurred prior to the cutting down of the forests.

Previous to our own generation, flood notes are rare. There is a great gap in which man has failed to put on record the coming and going of the mighty waters. Nature has, however, kept numerous water-gauges where the heights of the floods occurring long before our great valley was settled, are plainly recorded. These records in the lower Mississippi Valley have recently been read, and some of the results are given in this paper. It will readily be seen that the record has been faithfully kept.

Throughout the alluvial valley and on either side of the Mississippi River lie numerous crescent-shaped lakes which were once the main channel of the river, but are now, in some cases, many miles from it. The banks of these lakes, like the present banks of the river and the banks of all alluvial streams, were built up by the waters themselves, which have dropped the sediment particle by particle, till they have reached a height equal to the plane of mean high water. By determining the heights of these banks, not in one case, but in scores of cases, and knowing by observation the heights of the present floods, we can arrive pretty closely

at the heights of the floods which occurred before the era of fixed water-gauges began.

The data here used is compiled from the notes of the recent survey of the Mississippi River. When the survey was made, no such use of the notes was contemplated, hence they are not as full in some cases as desirable for a rigid discussion; but as all of the lakes surveyed have been considered, and as all of the results point to the same conclusions, they may be regarded as essentially reliable.

A few of the principal cases examined are given in detail below. These comparisons of old and new river banks, together with the accompanying map showing their relative locations, will, it is hoped, give a good idea of the importance of this testimony. The map was reduced from the manuscript charts of United States surveys made in 1882 and 1883. The figures represent the elevations of the banks in feet above sea level.

1°. Beaver Dam Lake, lying east of the Mississippi River, near Austin. The date of the cut-off is not known, but judging from the extent to which it has filled up, and the timber that has grown up in the former river bed, it must have occurred long before the surrounding country was settled. It is safe to call it at least a hundred years old. The old bank at the head of the lake, which is some three miles from the present position of the river, is the same elevation as the new river banks.

2°. Eagle Lake, lying east of the river, was formed by what is known as Terrapin Neck cut-off, which occurred in 1866. The head of the lake is about seven miles from the present position of the river, and the bank elevations are the same. The distance around the old channel was about seventeen miles, while the distance across the neck was less than one mile.

3°. Yazoo Lake, lying on the east side of the river, near Vicksburg. The Yazoo River empties into it. The cut-off is said to have been made in 1699. The head of the old lake is about seven miles from the present channel. The elevations of the old and new banks are the same.

4°. Palmyra Lake, lying on the west side of the river below Vicksburg, was made by the Davis cut-off in 1867. The head of the lake is about seven miles from the present position of the river, and the bank elevations of the two are equal. The distance around the old bend was nineteen miles; while the distance across the neck was less than one mile.

5°. Lake St. Joseph, lying west of the river, is of very early date, probably older than Yazoo Lake. The head of the old bend is about six miles from the present channel. The cut-off shortened the river twenty miles or more. It will be seen by reference to the map that the upper arm of this lake lies very near Palmyra Lake, and the elevations of the banks are practically the same.

6°. Lake Bruin, lying on the west side of the river, was cut off before the river was known to navigators. The elevations at the head of this lake are somewhat scatterring and uncertain, but are sufficient to show that the banks are practically the same height as the present river banks. The head of the old bend is now six miles from the present channel, and the distance around it is thirteen miles.

7°. Lake St. John, lying on the west side of the river, was cut off prior to the settlement of the surrounding country. The date is not known.

The head of the bend is some three miles inland, and its banks are the same elevation as those of later formation.

8°. Lake Concordia, lying on the west side of the river, a short distance above Natchez, was cut off long before the beginning of the present century. Surveys of 1810 show it practically the same as it is now. The date of the cut-off is not known. There have been two cut-offs in this same bend, and it is threatened with another one in the same vicinity. The banks along the head of the oldest bend are from five to seven feet higher than the concave bank of the present bend. But this is easily accounted for by the rapid caving going on in the latter. This caving has averaged 220 feet per year for seventy years, and the bank building process has not been able to keep pace with it.

The new-made land on the point opposite this bend, however, is as high as the highest land around the old bend.

The two more recent cases cited above are made use of to show that there is no essential difference between the elevations of the present banks, the banks of recently cut-off lakes and the banks of those lakes which date back perhaps centuries.

The banks at the heads of all of these lakes are generally above overflow at the stage which covers the present banks, and some of them are seldom covered even by the highest floods. The explanation of this is simple enough. In all alluvial streams the deposit is greatest where the water first leaves the channel. It therefore follows that the highest land lies along the immediate banks of the stream, and slopes rapidly off as we go inland. This slope in the lower Mississippi Valley ranges from one to ten feet per mile; hence the water, when it escapes from the banks, runs off with considerable velocity, and the surface of the water, instead of being level, conforms quite closely to the surface of the ground. The banks of the St. Francis River, at a point opposite Fulton, Tenn., are twenty-three feet lower than the banks of the Mississippi, and the high water of 1882 at the former was eleven feet lower than at the latter. In the Yazoo basin, opposite Helena, Ark., the high water at Coldwater bayou, 18 miles from the river, was eleven feet lower than at the river bank. In the lower part of the Yazoo basin and in the Tensas basin, the high water surface does not have so great a slope. The slope of the land is greatest near the banks. In extreme cases this amounts to a fall of thirteen feet in 200 meters (657 feet). The latter was determined by actual measurement.

It is plain to see, then, that the banks at the heads of the old lakes are above overflow, not because they are higher than the banks over which the water escapes, but because the water is lower several miles from the river, than it is when it first leaves the channel.

So far as these investigations have gone, all the evidence tends to prove that the change in flood heights, if any, is so small that it requires very long periods of time for it to become appreciable. The lapse of two centuries fails to show it. But the greatest changes, as far as the forests are concerned, have occurred within the past fifty years, and yet we find no corresponding change in flood heights. There can be no question that these silent monuments of past floods afford more reliable testimony than the statements of a casual observer, handed down through several gen-

erations. In the first case, we have absolute facts to deal with, which any one can examine and verify. In the other, the statements, which at first may have been true in a general sense, have been added to, warped, twisted, and colored by each one who has had a hand in transmitting them, till they are wholly unreliable.

It is hoped that the study of these old river banks will be extended in the near future so as to include all of the lakes in the alluvial valley. The results of such an investigation would be full of interest, and would yield much valuable information concerning the past history of the river and its floods, and would also give a clue to its probable action in the future.

DISCUSSION BY ROBT. E. M'MATH.

Though not disinclined to accept the main position reached in Mr. Ockerson's paper—that the mean height of floods in the lower Mississippi has not materially varied in consequence of deforestation and allied influences—I am unable to accept a comparison of the height of banks along the present and former courses of the river as affording conclusive evidence either of change or no change.

The claim that banks of old lakes afford a record of the mean height of floods for the time when these lakes were parts of the river bed, rests upon two assumptions :

1. That silt-carrying streams, which form their own beds, build their banks to the mean height of floods ; no higher, as well as no lower.

2. That the relative position of the old lakes in the river bed, of which they once formed a part, can be identified, and so a comparison made with the corresponding parts of the present river.

The first of these assumptions is a transferred generalization based on a study of tidal rivers. On these it has been ascertained that the height of bank formed by deposit is closely that of mean high tide.

The inference that the banks of a silt-carrying river must, therefore, represent mean height of floods, is not warranted. Tidal floods occur twice daily, or about 700 times a year; floods in the lower Mississippi scarcely once a year, and what is wanting in frequency is not made up by duration or activity, so far as we know. Consequently, the adjustment of height, if a law exists, may well be complete in one case and very imperfect in the other. But there is no law shown, only a tendency for the accumulation on the margin of tidal flow to reach the extreme height to which material can be borne; progress of course being at a rapidly diminishing rate as height increases. Given unlimited time, and the tidal margin should reach the height of spring tides. But in a river which has made, and is making, cut-offs, one is debarred from allowing the time required for any such results. If the assumption is to be admitted in the case of periods represented by the old lakes, it must also be applied to the present bed. In that case levees should be needed only to guard against extraordinary floods, which is not the case. Clearly, if the banks of the Mississippi do not now represent mean flood height, one may not assume that they ever did.

The second assumption, of a sufficiently accurate identification, to warrant comparison as between corresponding parts of the river, is put

in doubt by the facts stated in the paper. The several cut-offs are said to have shortened the distance between points by as much as 20 miles in some cases. At 3 inches normal slope per mile, 20 miles would be 5 feet, making the matter of identification one of great importance and difficulty too, for after the cut-off the corresponding part may be but a mile or even less in length in the case of a recent cut-off. Who, then, can identify an old one?

Taking the case of a recent cut-off, after the new channel has attained full development and the river ends of the old channel silted up, one would expect a local lowering of the river as a first consequence. Wherefore, comparing the height of old banks and the new water plane, the old bank would be relatively higher than it was when the river flowed along it. If the new bank be built up to the same elevation as the old, it must then be relatively the higher in relation to the new and lowered water plane than the old bank was to the old plane. Whence, on the theory of the paper, the conclusion would be unavoidable that flood volume had increased, but increase of flood height was held in check by the cut-off.

To take another view. The shortening by a cut-off is local and, probably, temporary. In the readjustment of the disturbed slope, the greater part is likely to be distributed above the cut-off, and, under the increased current caused by increased slope, erosion will be active and the recovery of length will also be mostly above the cut-off. Hence, the ultimate effect is to make the head of the cut-off occupy a position in the readjusted river, several miles further down stream than it originally was; therefore, if the bank again attains the height of the old one, it would, on the theory of the paper, be indicative of increased flood height.

I present these arguments, not as my belief, but as illustrations of how a conclusion, contrary to that of the paper, might be reached from the same data and theory, and so to show the insufficiency of the evidence presented by the old lake banks. My objection to the first assumption, for which Mr. Ockerson is not responsible, that it is no more than an unproven hypothesis, is fundamental. The illustrations above allow it, therefore the conclusions share in the doubt. This doubt is much strengthened by the fact, that banks of known recent formation are in some instances above overflow, even by great floods, and that for considerable areas. On the other hand, the fact that some banks are now relatively lower than mean flood level has been used, relying on this same assumption, to prove the "Degradation of the banks of the Mississippi," and so an argument was framed for levee construction by the general Government. From the facts we, therefore, see that banks are now both higher and lower than mean flood level, and have no warrant to say that it was otherwise in prehistoric times.

Whether clearing and cultivating the soil has increased the frequency and violence of floods, and whether the discharge of streams has on the whole been changed, are two distinct questions, which have been greatly confused in the discussions alluded to by Mr. Ockerson in his paper. A like confusion characterizes what may be called a division of the first of the above questions. That is, a distinction should be made between increase in volume and height of the rare and, so to speak, phenomenal floods, as that of 1884 in the Ohio, and increase in average

flood height. The latter is the point upon which Mr. Ockerson's paper bears; the other is not touched upon. In the popular estimation, the first of these is the more prominent; as bearing upon river physics the great and rare floods are of less consequence than the lesser and more frequent floods which largely control the mean.

DISCUSSION BY J. A. OCKERSON.

There are some statements in Mr. McMath's discussion to which I wish to call attention.

1. The claim that the bank elevations are equal to mean flood height, he regards as an assumption. So far as the conclusions reached in the paper are concerned, it makes no difference whether this be true or not. That there is *some* relation between the height of the banks and the floods which produced them, no one can deny. The fact remains, whether we know the laws which regulate the deposits or not. The relation between the height of the present banks and the floods which deposited them, must be essentially the same as that which existed during the early periods quoted in the paper. Therefore, a comparison of the bank elevations certainly affords a reliable means of comparing flood heights.

2. He states that we cannot identify the relative position of the old lakes in the river bed of which they once formed a part.

Every one who is familiar with the topography of the lower river knows full well that the position of the river can be traced out from where it left its old channel, around the old bend, and down to where the old and new channels meet again, with almost as much certainty as we can run out its present banks. In this discussion, one thing should be borne in mind. The *great* changes in the position of the river bed are local, such as produced by cut-offs, while by far the greater part of its length remains practically stable. Hence it is plain to see that the question of relative location is a simple one.

In a careful contour survey, covering an area which includes the old lakes and the present river, the outlines of the old river are so plain that there can be no mistake, even where the old bed has been nearly filled up by deposit. Surely when such facts as these are used as evidence, it cannot justly be regarded as an assumption.

In attempting to show the insufficiency of the evidence presented by old river banks, Mr. McMath has made use of hypotheses which, being erroneous, have led him to wrong conclusions. He assumed that after a cut-off the greatest changes, caused by the river readjusting itself, occur above the cut-off; hence the old bend is relatively further down stream.

A single case will, perhaps, be sufficient to show the fallacy of this argument. Take the cut-off immediately above Natchez. In this case we have a series of surveys extending back some 75 years, the oldest of them being made some time after the cut-off, but before the readjustment had fairly begun. We now find by comparing the positions of the river as shown at these intervals, that the new bend has been steadily pushing out into the old one, and will more than likely flow along the old banks again, while immediately above and below the cut-off the channel has remained practically in the same position. There can surely

be no doubt in this case, and there are others which afford evidence equally good.

The fact that the banks are in some cases higher, and in others lower than mean flood level, is not questioned, but these conditions are exceptional and can generally be traced to local causes ; hence they have really no bearing on the question.

If the investigations concerning the old lake banks had been confined to a few selected cases, then the objections urged as to the adequacy of the testimony would perhaps have been valid.

But when numerous cases are considered, some of which are beyond all possibility of doubt as regards relative location and other necessary facts, and where but little doubt attaches to the other cases, and where the facts are all treated in the same manner, then it must be admitted that as the results all point to the same conclusion, the evidence is sufficient, at least so long as there is nothing but theory to controvert it.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

ON THE RIVER AND HARBOR BILLS OF THE U. S. CONGRESS.

By Clemens Herschel, Member of the Boston Society of Civil Engineers.

[Read January 14, 1885.]

I invite the attention of the Society, this evening, to some thoughts of mine on a topic which, it seems to me, is far from being generally well understood. It is one to which but little thought has been given in this country, especially not in the 50 years last past. Of which, indeed, it may be said, that it was much more prominent, in the early days of the Republic, in the minds of the statesmen of the time and of the people, than it is to-day, and that an awakening to its national importance, in our own times, would be but a return to the ideas of the fathers. I allude to the general subject of internal improvements ; of works of the civil engineer, for facilitating the movements of commerce among the States and with foreign nations ; a noble train of ideas, covered up and buried from sight, however, within a year or two. by one great cry of discontent, which did not stop to reason calmly or to discriminate. "Let us burn the barn," said the multitude, "and we will kill the Cheesequake Creek, or some other mouse or rat." Such, I submit, was the public excitement over the veto and the failure of the 1882 "River and Harbor Bill."

If we seek for the reason why internal improvements occupied so much more of the attention of leading men in 1830, and previous thereto, than they have done since, or do even now, it will be found, I think, in the introduction and construction of railroads by private capital. Here was a means of freight and passenger transportation, which, at a bound, surpassed all that the most ardent patriot or prophet of the benefits to be gained by his country by the construction of canals or of river improvements, could possibly have foreseen. No wonder, then, that his occupation became lost to him. Nor had he naturally any successors. That school of politicians and of statesmen came in, who believed in accomplishing

everything needed, in the way of internal improvements, by private capital. Railroads could and were built and operated by private capital, and what private capital would or could or did not accomplish, was not worth the having. Not only was private capital given free rein, to go where it pleased, take what it wanted, and build what it chose, but it was aided by the credit and by grants of the state—until we are now brought face to face with a development of private capital, such as threatens the well-being of society, and the ingenuity of statesmen almost stands aghast at organizing any control of the monopolies which have been allowed to grow up and flourish. The creature stands to-day fairly threatening its Creator. It has come to be learnt, however, that no method of controlling, for the public good, the vast corporations called into being by the invention of the railroad and of the locomotive (and many such have been, and are yet being tried) is quite so effectual as the silent, quiet, healthy check put upon them by the competition of public water-ways.

If New England has to-day cheap bread and cheap meats, it is largely because the energy and statamanship of DeWitt Clinton constructed the Erie Canal; because the genius and the indomitable will of James B. Eads put 30 feet of water at the mouth of the Mississippi River, where formerly there were but 12 feet; it is largely because the Dominion of Canada, urged on by the stern necessities of her soil and of her climate, and with a larger public spirit shown by its Government than is shown by Congress, has converted the serried St. Lawrence into a noble pathway for water-borne commerce. Navigable for the large ocean steamers 200 miles inland, to Montreal, that imperial city of commerce, whose wealth has been founded on the wisdom and the work, hand in hand, of her citizens and of her statesmen, it is practically continued thence, by the most magnificent system of canals on this continent, from Montreal to the Great Lakes. So that the miller of Minneapolis is to-day grinding wheat, "on orders," to be shipped by water *around* the United States; and our own flour and bacon and beef is to-day cheaper to the European laborer, than it is to the consumer here in New England.

The natural consequence of this and of similar facts in commercial history is a great revival of interest in the construction of canals and in the improvement of natural water channels. Here, no less than abroad, canals are looked to by governments, by statesmen and by far-seeing citizens, as a needed accompaniment of other means of communication, such as common roads and railroads; and the development of river and of ocean or lake navigation is favored as a most beneficent factor of civilization, and of the advantages which civilization confers upon a people. A few points of difference between freighting on railroads and on water channels may at this place be pointed out. The first railroads were chartered to provide an improved track for and to charge a toll upon the vehicles of the public, following the customs of the times, as exhibited on the turnpike roads or canals then in vogue. But it was speedily seen that such a use of railroads was incompatible with the safety or the regularity of transport, and the railroad companies became the owners and operators of the vehicles, no less than the proprietors of the track. This is the fundamental difference between railroad and all

other means of transport, ancient or modern. In no other case is it usual, or necessarily desirable, that the company owning the pathway shall at the same time be the contractor for moving freight and passengers, or be the "common carrier." It may very well happen, therefore, that the same person will argue against any form of government railroad, and yet be a firm believer in government canals, or an improvement of rivers by the general Government. These latter are, in effect, but another kind of highway, in which boats, tugs and steamboats take the place of wagons and of horses, while a water channel takes the place of a road surface. And they should be as free of toll, while open to the public, say the advocates of internal improvements, as are the highways of to-day. The test, which has been suggested, that river improvements should not be undertaken by the general Government, unless the tolls exacted on the improved river could pay for the improvement, is as inapplicable as it would be to apply the same test to the construction of a new county road. The world has outgrown these petty imposts levied from step to step throughout the country. Tolls on rivers and on inland canals are to-day as much out of place, as a rule, as they are on bridges, on highways or at the confines of a city.

I need not stop here to prove the necessity of a control, in the interests of the people, of railroad corporations. I shall assume this much to be an acknowledged fact. No one will probably be readier than I, to give to control by Railroad Commissioners, or by direct legislation, the credit which properly belongs to those methods. But an examination into the workings of those methods must, I submit, convince any one that they are tentative, and that they deal only with the marked abuses of traffic monopoly. Worst of all, they fairly invite a meddling with the legislative functions, by parties directly interested in such legislation. It is true that the "state of Camden and Amboy" has passed from the history of the times, but only because it has been engulfed in a grander empire, or because we have become callous to similar forms of servitude. Under another form, not working with such utter disregard of public decency, but yet active, ever present, easily outwitting the public on more than single occasions, the old Camden and Amboy *régime*, as it existed in New Jersey, may be observed in full being at the State capitols of probably all of the States of this Union, not to speak of the capitol of the nation. Let us cite but a single instance, the neighboring State of Connecticut and its relations to the road which controls it. Take, as an illustration, the debate upon and the failure of the "short-haul"* bill in the winter of 1883–84, when it passed the popular branch with more than three-fourths voting for it, but failed to pass in the Senate.

It is seldom that any evil can be effectually met by legislation formulated in direct opposition to it. Some evils defy such legislative inter-

*The "short-haul" bill (in force in Massachusetts) was intended to provide that: "No railroad corporation shall charge or receive for the transportation of freight to any station on its road a greater sum than is at the time charged or received for the transportation of a like class and quantity of freight *from the same original point of departure* to a station at a greater distance on its road in the same direction." In the absence of such law, railroads can and do compel small, non-competing points to pay excessive freight rates. With the usury so gained, freight is carried below cost to competing points, and competing water and other lines are crushed out of existence. Small towns are kept down or are killed off, while the larger, central points, or some of them, profit by the struggle; it may be, however, that they profit only so long as a certain competition exists and until their turn to suffer shall have arrived.

ference. Legislation should go deeper, and should strike at the causes of evil. The indirect method of procedure will generally, perhaps always, be found the most effectual in the attack on mundane politico-economical evils. Such a method, as applied in line of a control of a government of the people by the railroads, is found in the development of the water-ways of a nation. Need a nation hesitate in the creation of far-reaching public works?

"What constitutes a state?" Says the poet:

> "Not high-raised battlements, or labored mound,
> Thick wall, or moated gate;
> Not cities proud, with spires and turrets crowned;
> Not bays and broad-armed ports,
> Where, laughing at the storm, rich navies ride:
> Not starred and spangled courts,
> Where low-browed baseness wafts perfume to pride.
> No! men—high-minded men—
> With powers as far above dull brutes endued
> In forest, brake, or den,
> As beasts excel cold rocks and brambles rude."

Not to take this literally, the poet means to say, evidently, that not only "bays and broad-armed ports, cities proud, thick wall, and moated gate" are requisite to constitute the state; in addition to these, there must be men—high-minded men. The very enumeration of all these works of man by the poet proves, however, the converse proposition which I venture to put before you: That the existence and maintenance of a wisely designed system of public works is also a necessary requisite in constituting a state. I think that we must all feel instinctively that with the removal of public works comes barbarism, or at least a primitive civilization.

Says another poet:

> "Bid the broad arch the dangerous flood contain,
> The mole, projected, break the roaring main;
> Back to his bounds their subject-sea command,
> And roll obedient rivers through the land—
> These honors Peace to happy nations brings;
> These are imperial arts, and worthy kings."

This country is but a young nation, sprung but yesterday, as it were, from a colony which could not be expected to excel in, or indeed to have, any public works. But no strong nation has yet existed, whether empire or republic, which was not distinguished for improving so much of the face of the earth as was controlled by it, to the greater, more beneficent uses of man. Here is a field for the employment of revenue in which it is nigh impossible, unless we include damage to the works themselves from waves and floods, to *waste* the sums expended. The result attained may, indeed, at times not be worth the cost, but there will ordinarily be *some* result, and one of some value. It may bring a small or no return in the way of direct income, and yet be of prime advantage to the body politic. No one pretends, nowadays, that highways shall bring in revenue; yet highways must be. New York State or City will not suffer, though the maintenance of the Erie Canal be a burden on the State.

Says Senator Hoar:

"There are few objects of expenditure which do not perish with the

using. There are fewer still which survive the generation which has created them. A few works of art, a few temples and public buildings, a few dwellings, kept for curiosity rather than occupation, a few great libraries, are all of the possessions of our day which will survive a hundred years. The money you have appropriated for the army, the navy, the post-office, the courts, for the cost of legislation, for the diplomatic service, for pensions, will leave no trace behind when the year in which it has been expended shall have passed. But the works which this bill authorizes will remain, making their annual and perpetual returns, instruments of commerce, of union, and of peace, so long as the waves run to the sea and the sea beats upon the shore."

In the construction of public works, the money expended is for the greater part kept within the country, is paid out to its own citizens, or should be, in any well-organized state. It has only circulated, but has nevertheless left visible and beneficial results in its wake. The visitor to Salzburg, in Austria, will be shown a tunnel through one of the mountains which surround it, and will be told that centuries ago there was a famine in the land. The then ruler of that little state, an archbishop of the time, caused this highway to be hewn through the rock, that the people might have useful work to do; and not only those then living, but ten subsequent generations of men, have profited by his wisdom, with numberless generations yet to reap the benefit of the work. Let me take the society into my inmost confidences, and submit to it a passing thought I have had, though I have had that thought many times. I dare not formulate it as a principle in political economy, for I confess I do not understand that science. In matters politico-economical I act mainly from instinct. But it has seemed to me that the circulation of money, in nations and with individuals, was like the circulation of water through the water-reservoirs and their concomitant pumps and windmills, which one sees in Holland. The surface of that country is so flat, that dirt, as we shall presently see, instead of being the synonym for cheapness, as with us, is in Holland a very dear article. If dug in any appreciable quantity, the result is a pool of stagnant water. This being against the public health, the creator of such a pool is obliged forever to maintain a pump and some motive power, usually a windmill, whose function it is to pump water out of the pool at one end, that it may be allowed to run back again at the other, thus keeping up the circulation and preventing stagnation. What more does a wise expenditure of money ever do, to the tokens of visible wealth, than is done by this pump to water? Once in a while, and for a brief span of life, or may be for several generations, some one elevates some of the life-giving fluid into a little private reservoir of his own, instead of letting it run back again into the pool, holding the accumulated wealth of the body politic ; but its tendency is always back to the common receptacle, and eventually it all gets there. Meantime the labor of the people goes on, but all it seems to do is to pump up money at one end and to let it run in again at the other. The object to be aimed at seems to be to cause the precious liquid to do a maximum amount of work on its everlasting circuit. Is it not well with the nation if, while thus circulating, it renders the face of the earth more habitable to man? So long as the work actually accomplished has been

a useful one, and one worth the expenditure of the forces involved in its construction, to somebody or to some people, is it not well worth while, to the nation as a whole, that it has been accomplished?

To be sure, it may have diminished the amounts stored up in certain private reservoirs above named, but what of that, in the broader view? The money spent has not been lost, any more than that is lost which has been spent for a hat, a coat, or a barrel of flour. It has changed hands; it has circulated. It is then meet and proper that a nation build public works, certainly when built with its own funds, and in a business-like manner.

The objection most commonly brought against public works in our own republic is, that our form of government is not fitted for their proper construction, and argument upon this point is capable of great expansion. Without going into constitutional questions, I submit, mainly, that this nation, or any of its States, can do anything they ought to do. If not immediately, then following a proper organization for the service contemplated. It is, of course, difficult or impossible to draw the precise line where the business of a government should end and that of private capital begin. In the post-office, that line seems at present to be drawn at a package weighing four pounds, and at means of transmission which carry the identical embodied form of intelligence submitted for transmission. Just why a package weighing seven pounds should be refused by the Government, does not appear, unless it be by the accident of a large private express business having become established before the Government thought of carrying packages. Until the Government shall have a "parcel post," as in England and all over the Continent of Europe, we submit to having the United States partitioned up among a half-dozen express companies, as was Poland by the three emperors, and submit to paying extortionate charges on all expressing not from one of the centres of trade to another or to a town within the district of the express company primarily intrusted with the package sent. This is a fair illustration of the difference between Government service and the service done by private enterprise. The United States mail carries a letter for two cents from anywhere to anywhere else. Express companies charge more for a package from one small town to another, within 50 miles, than they do for hundreds of miles of carriage, where competition controls the charges. The tendency of all private transportation is to make the big cities bigger, and to crush out all the little ones. Whereas government service treats all alike. Similar fault can be and has been found with the Jay Gould monopoly of the Western Union Telegraph, and some day the transmission of intelligence, in whatever form demanded, may be transferred to the Post-Office Department, as is already the transmission of intelligence by letter.*

* Since this was written, the newspapers have contained the following: "New York, Nov. 5, 1884.—Early this morning the wires of the rival telegraph companies to the Western Union were cut through all the northern part of the State, so that the only means of communication is over Jay Gould's wires. From dispatches thus received the Republicans are claiming the State by 5,000. Word has been sent to the 30 Republican counties to hold back the returns. There is no question but that the Fifth avenue managers have determined to count this State for Blaine, if it is within their power. Gould's active work in this direction is not denied." Not to argue too much, from an item of this sort, parts or all of which may not be true, it is safe to cite it as proving that it is decidedly detrimental to the public interests, to have a public service, like that of the telegraph, in the hands of a monopoly, whose leading spirit is at the same time the largest speculator in stocks and bonds that there is in the country.

Water-works for cities, it is acknowledged, should be owned and administered by the people and not by private capital, though occasionally the people are caught napping and only liberate themselves from water monopoly after years of agitation. But we have agreed, I believe, that where private capital has assumed proportions and powers so overshadowing the public weal as do those of our large railroad corporations, it is the duty of the Government to hold it in check. It is an acknowledged fact that the development of water-ways will constitute such a check upon these powers. Unless some better means can be devised it becomes the duty of the Government to apply it, and if the Government is not so constituted that it can properly do this work, the people must see to it that the Government be adequately amended or reconstructed. Such a process need alarm no one. It has been going on all around us for more than two hundred years. Compare the original form of town government, when the few original settlers could meet and vote, as was done,* that "Cornelius the Irishman have leave to take up land, but provided he have no voice in the town affairs," with the latest forms of city charter. Cornelius probably made his own pathway to his own lot. To-day the Board of Public Works has charge of the sewered, water-piped, gas-piped, paved, electrically lighted, wire-strung and horse-car ridden street that leads to the same lot of land. Extend the demands of civilization to the State in the same way that they have already been felt in those parts of the State where population is most dense, namely, in the cities, and forms of State government will soon adapt themselves to the work they have to do. City governments are constantly being modified and improved in this very direction, and State governments could as easily be molded to conform to the requirements of the public and of public works.

The powers of the general Government have undoubtedly had a restraining influence on public works, or on an organization for public works, by the several States. And unfortunately, the organization of the general Government itself, to carry on public works, leaves very much still to be desired. Let those who may shun the proper organization of the States and of the general Government for the systematic construction and maintenance of public works think of one thing—no nation has yet existed that was wholly without them, and this nation, no less than most or all of its States, in spite of all obstacles, has had them, and *is constantly having them.* The question becomes reduced then to this simple proposition: Shall our public works be built, and, what is of equal importance, maintained, in a proper, business-like manner, getting year by year a dollar's worth for a dollar's expenditure; or shall the shiftless, hand-to-mouth method of procedure, which looks not forward, and hides its shiftlessness by denying that we have any public works—shall this wastefulness of the public funds be allowed to continue?

Let me quote at this point from Senator Hoar's speech of July 1, 1884:

I am one of those persons who believe the powers conferred by the people on the National Government were created to be exercised. There is no economy in wasting strength. Nothing is so extravagant as suffering great public properties to remain unused. Great as have been the

* See Dwight's "Travels in New England," 1796-1802.

achievements of the American people in developing the resources of this continent for the use of man, there are far greater resources still unused, which the power of the nation alone is adequate to unfold. Nothing stands in the way of our contesting again with Great Britain her supremacy on the sea, of taking our rightful and leading place in supplying the markets of the world, as well as bringing together the distant parts of our own territory, and multiplying many fold our agricultural and mineral wealth, but the want of a discreet and liberal exercise of the powers vested in Congress for this very purpose.

There are two difficulties which we encounter. The first is from that school of statesmanship which dreads and resists every exercise of the functions of government not absolutely necessary for the preservation of the state and the security of life and property. The other is from a widespread popular belief that this class of expenditures is dishonestly made. But the theory of the strict constructionist, however it may be vindicated by experience, in regard to many of the relations of government to the people is surely out of place here. Government has its police powers; it exercises its authority for restraint or for exaction over the individual human will. The use of such powers should be confined to the limits of absolute necessity. They become odious to those who are subjected to them. They are the instruments of tyranny and the temptation of ambition. Let these powers be limited by a construction as strict as may be compatible with the absolute safety of the state. The maxim, "The world is governed too much," is the witness of the experience of mankind of their abuse.

But to the power to regulate commerce no such objection applies. It is wholly beneficent. It is a senseless and unreasoning fear which dreads putting forth the national strength in these great public works through which every artery and vein of commerce throbs with a new life. Surely if we can call the great inanimate forces of nature into the service of man we may rightfully avail ourselves of the united strength of the 50,000,000 who make up the Republic to build great public ways, to aid the railroad, to open the harbor on lake or ocean, to clear the channel of the great river for the commerce of the world. Under this generous and wise policy taxation itself, everywhere else a burden, becomes only a source of wealth. * * * Certainly the Republic is a failure if it cannot wield those national forces which are solely peaceful and beneficial, because of the iniquity and corruption which must attend their exercise.

Who can doubt that a sovereign like the half-savage Peter the Great or like the accomplished Emperor of Brazil, would largely increase the value of our product to the producer and reduce its cost to the consumer, by moderate and judicious expenditure in removing the obstructions to transportation? What I complain of is, not that we do not adopt the methods of other nations. Our own may be better. I do not now complain that we do not imitate Great Britain in the policy by which she has gained and preserved the sovereignty of the seas. I do not now complain that we do not create a navy. I am not at this moment complaining that we have neglected the lessons of our own experience and the conclusions of our wisest and most thorough investigators. But I demand that we shall consider all these things on their merits; that we shall treat them and discuss them and vote upon them as things that may be honestly done or honestly let alone. I would insert in the river and harbor bill no single item the public usefulness of which can not be made so clear in the report of the committee that it will command with substantial unanimity the support of those persons who will fairly and consistently give it their attention. If the American Congress shall be driven from its duty by fear of imputations upon its integrity, it will go far toward a confession that such imputations are not undeserved. * * * * *

The removal of the burden of the cost of transportation of food and material, important as it is to the rest of the country, is vital to New England, and especially to the State which I represent. She has to transport over vast spaces her food, her material, and her product. Bringing

across the continent her food, her coal, her iron, her leather, her wool, and her cotton, she sends her product back across the continent to be sold in competition with the established industries and cheap labor of Europe on the one hand, and the rising home manufacture of the West and South on the other. Boston, of all the five great ports of export, is the farthest in distance from the producer. New England is the farthest in distance from the market of all the great manufacturing centres. The interest of New England is to make the percentage of the cost of transport on food and material and product as small as possible. That alone can give her equality.

The doctrine of internal improvement is a Massachusetts doctrine. She originated it. She has furnished its ablest and most zealous defenders. In a letter dated February 2, 1837, John Quincy Adams says:

> The great effort of my administration was to mature into a permanent and regular system the application of all the superfluous revenue of the Union to internal improvement; improvement which at this day would have afforded high wages and constant employment to hundreds of thousands of laborers, and in which every dollar expended would have repaid itself fourfold in the enhanced value of the public lands. With this system in ten years from this day the surface of the whole Union would have been checkered over with railroads and canals. It may still be done, half a century later, and with the limping gait of State legislation and private adventure. I would have done it in the administration of the affairs of the nation; I had laid the foundation of it all by a resolution offered to the Senate in 1806, and adopted by that body under another's name. The Journals of the Senate are my vouchers. It called forth the first report of Albert Gallatin, then Secretary of the Treasury, upon internal improvement.

This report of Albert Gallatin was made to the Senate on the 4th of April, 1808. Few of our state papers equal it in interest and importance. It embodies the opinions of John Quincy Adams, as he repeatedly declared. Gallatin's own authority is hardly inferior to that of Adams.

I give a brief abstract of Mr. Gallatin's report, which shows its far-reaching character:

> Whenever the annual expense of transportation on a certain route in its natural state exceeds the interest on the capital employed in improving the communication and the annual expense of transportation (exclusively of the tolls) by the improved route, the difference is an annual additional income to the nation.

It makes no difference whether the tolls pay the interest on the cost or not.

> The general gain is not confined to the difference between the expenses of the transportation of those articles which had formerly been conveyed by that route, but many which were brought to market by other channels will then find a new and more advantageous direction; and those, which on account of their distance or weight could not be transported in any manner whatever, will acquire a value and become a clear addition to the national wealth. * * * * * * *

Mr. Gallatin proposes to defray by an annual appropriation of $2,000,000, extending over a period of ten years.

Mr. Gallatin estimates the annual permanent revenue of the United States from 1809 to 1815 at fourteen millions, and the necessary annual expenditure on the peace establishment at eight millions and a half, including forty-six hundred thousand for principal and interest of the public debt.

It will be seen, therefore, that he proposes an expenditure for internal improvements alone, not reckoning any sum devoted to harbors, either on the ocean or lakes, equal to 14 per cent. of the entire national income, and equal to about 25 per cent. of the sum expended by the nation for all other purposes, and to more than 50 per cent. of the expenditure for all other purposes, exclusive of the public debt. The actual expenditure fell far short of Mr. Gallatin's estimate, being but fifty-three hundred and eleven thousand in 1810 for all purposes other than the debt.

If we were to expend the same proportion of our revenue on this object to-day, as was proposed by Gallatin in 1808, we should have devoted fifty six and a half millions in 1882 to internal improvements alone (instead of fifteen millions, as proposed).

Let it be remembered that the expenditure thus proposed by these early statesmen was for internal improvement alone—for rivers, canals and roads—an expenditure for the service only of domestic commerce, including nothing for light-houses or harbors on the coast. John Quincy Adams would have had a nation of six or seven million people give five

million annually from its revenue of fourteen million. Jefferson would have it give annually eight million from its revenue of eighteen million to the territory east of the Mississippi for purposes for which the much-abused bill of 1882 expended, exclusive of the Mississippi River, but five and a half million from our income of four hundred million for the entire continent.

I suppose we may fairly claim that any doctrine upon which, from 1806 to 1848, when Adams died, Daniel Webster and John Quincy Adams were agreed, was a Massachusetts doctrine.

To exhibit Mr. Webster's views on the policy of liberal expenditure for internal communications by the General Government would be almost to set forth his whole theory as a constitutional statesman. He was born in the last year of the Revolutionary war. His public life began at the beginning of the war of 1812, when the infant Republic, with its population scarcely exceeding 7,000,000, was an object of undisguised contempt to every leading power on earth. Yet the present greatness of the country is not seen by our own vision to-day more clearly than it appeared then to that of Daniel Webster. With the eye of a prophet and the comprehension of a statesman, he saw from the beginning the vast and beneficent power of these unused national forces. He never separated from the blessings of constitutional liberty itself the benefits to be derived from commerce as developed by these great national works of internal development. He never omits to urge this theme when the occasion makes it proper. * * * At the public dinner given him in Faneuil Hall, in 1828, at the outset of his service in the Senate, he again calls the attention of his constituents to this subject as one of great and growing importance. * * * "The vast regions of the West are penetrated by rivers to which those of Europe are but as rills and brooks. The navigation of those noble streams, washing as they do the margins of one-third of the States of the Union, is obstructed by articles capable of being removed, and yet not likely to be removed but by the power of the general Government. Was this a justifiable object of expenditure from the National Government? Without hesitation I have thought that it was."

He goes on to urge that these objects are much less local than they seem :

"If the mouths of the Southern rivers be deepened and improved, the neighboring cities are benefited, but so also are the ships which visit them ; and if the Mississippi and Ohio be rendered more safe for navigation, the great markets of consumption along their shores are the more readily and cheaply approached by the products of the factories and fisheries of New England." * * * * * * *

All expenditures we have ever made or ever proposed on lakes, rivers, and harbors together are trifling compared with what our rivals are putting forth to maintain themselves against our competition. We have 23,000 miles of stormy and dangerous coast line on the oceans alone. England has but 1,300 ; yet she expended fifteen millions on her harbors in 1874.

The breakwater at Plymouth cost her \$7,214,325. That at Portland cost her \$5,043,870. Holyhead cost her \$6,499,895. The total expenditure of the Clyde Trust to June 30, 1875, was £6,774,315, or about \$33,000,000, a sum greater than we had expended on all our rivers and harbors together from the foundation of the Government to 1873, and three times as much as we had expended on our 20,000 miles of Western rivers. This outlay has converted the Clyde from a shallow stream, fordable at many points between Glasgow and the sea, into a river capable of bearing on its waters the commerce and ships of all nations. Yet we are accused of extravagance when we would devote a fifth part of this sum to the thousand miles of the Mississippi. I cannot give the expenditure upon the Mersey. But the debt of the Mersey Docks and Harbor Board outstanding in 1882 was \$81,424,405. * * * * * *

Canada enlists in the competition with an expenditure on her Government railroads since 1868 of \$30,406,481. She subsidizes a line of steamships to Brazil. In 1880-81 she paid on capital account \$8,176,316, of

which $4,968,503 represents outlay on the Pacific Railroad, $608,702 on the Intercolonial Railway, $1,242,903 on the Welland Canal, $411,608 on the Ottawa canals, $334,681 on Dominion lands, and the remainder on the other canals. In the same year she spent $2,900,000 on public works. In the year after the union of her two provinces, Canada, with a population of little more than a million and a total revenue of $1,488,000 expended two millions for her canals. * * * * * *

I take the following from the Edinburgh Review for October, 1882:

In brief, the actual water-ways of France amount to an aggregate length of 7,069 miles, not including any maritime navigation, such as that of the Seine below Rouen. The cost of this fine system has been £43,608,516, or £6,230 per mile. One thousand eight hundred and thirteen additional miles have been authorized and are in course of execution by the state, the cost of which, together with that of the improvements required on the existing lines, will at least be an equal sum. France will shortly be possessed of 8,880 miles of inland water way, provided at a cost of from £80,000,000 to £100,000,000. * * * * * *

These statistics become doubly impressive when we reflect that we have a single American State, one only among our thirty-eight States and eight Territories, which is as large as France in territory and far greater in its rich and various productive capacity. * * * * * *

I desire to discuss but one more branch of the subject. Granted the desirability of public works and a form of government fit to execute them, how shall the choice be made among the many projects which active minds will ever press upon the law-making power? This is the precise phase in the growth of any public work, in which the public is most apt to find dissatisfaction. I believe that the experience of foreign nations, especially that of the leading foreign nations, who have had centuries of experience in this branch of the subject, would be very instructive. A commission appointed for the purpose of devising a system of rules and regulations in the testing of asked for appropriations for public works, would, I believe, (at all events could), make an interesting report. And until I had made such study, I would not wish to suggest something better, where I have dared to criticise. In England an attempt has been made, extending from some 20 years back and yet in action, to abolish Parliamentary grants for river and harbor works, and thereby do away with the selection of works made necessary by the policy of making such grants. Most every conceivable substitute has been tried: To loan money to the local authorities, at a low rate of interest; harbor dues and tolls to repay the loan. The result has been that the loan commissioners, with an eye single to good security, have choked off most of the works, say half of which, it is now admitted, they should have encouraged. In other cases they have loaned money, the works have been started, not finished, they have refused further loans, no income has resulted, the original loan has been defaulted; and as a final upshot of it all, dragged along over 15 or 20 years of weariness to the spirit, they have made a stingy Parliamentary grant in the form of a defaulted loan, and all this without doing much, if any, actual good.

Sometimes the system has been followed of giving one-fourth or one-half, if the local authorities gave the other three-fourths or one-half. And some harbors of refuge, so called, have been built by convict labor. Navy harbors, harbors for docks and war establishments, were built by the Imperial Government outright. Some of the smaller dependencies of Great Britain, such as the Isle of Wight, have never had any system but that of legislative grants outright. On the whole, a study of the

systems tried in Great Britain* has led one student thereof to stand ready to pronounce her schemes and plans of finance for harbor improvements a magnificent failure, with more to be learnt in what is to be avoided than in what is to be followed. Of late years, the improvement of small fishing-boat harbors has become an object of private charity, no less than of Government aid; the Baroness Burdett-Coutts, among others, having developed several such harbors in Ireland, besides furnishing fishing boats to the population, the latter on loan, to be paid for out of the catch. This has been done to develop the fisheries, and to keep the population from want and misery. In Scotland there is a special commission to aid the fisheries in this way, who exact wharfage and other dues as a means of return. A charge for branding the kegs of fish, without which brand the fish are not salable, is one form of mediæval tax, thus exacted. My own view of the majority of these many charges for brands on herrings, multifarious wharf-dues, harbor dues and similar complex Government tolls, is one of fair-sized contempt. "Some merchants conduct their affairs after the manner of statesmen," it has been said, "while some statesmen conduct their business of State after the manner of peddlers." The business of taxation of the people should be simplified to the last degree: a few taxes, equally imposed; all expenditures from the amount thus collected. This, it seems to me, is the tendency of modern times, and seems the only business-like method of carrying on the State government. I believe that no other nation has ever tried experiments similar to those tried in Great Britain. The better governed a country is, the simpler, the better its public works are managed; so much is certain. Such small states as Holland, Belgium, Baden, and, as we have seen, a snug little dependency, even, of Great Britain, like the Isle of Wight, are models in the management of their river and harbor and other public works.

As a type of the continental practice, I give the system in vogue in Prussia. I have it from a member of the Prussian corps of civil engineers, several years resident in this country as engineer attaché to the Imperial German Legation at Washington, and translate literally. It is undoubtedly as correct a representation as it is an able one.

"Prussia is divided into river and harbor districts, having a chief engineer (Regierungs und Baurath) at the head of the work for each district. The several districts are again divided into a number of lesser circuits, having a State Inspector (Bau-Inspector) as resident engineer in each. Resident engineers are furnished with assistants, according to their needs, mainly such who rank as engineers (Baumeister), and have passed both the Government examinations, and such who may be called assistant engineers (Bauführer) and who have passed only the first Government examination. Engineers and assistant engineers are employed by the State per diem, according as the State may have need of their services. They may accept service on works built by private capital. According to their length of State service, they advance to permanent State positions, as inspectors or resident engineers.

* See a "Blue-book" of 1883, entitled "Report from the Select Committee on Harbour Accommodations," together with the Proceedings of the Committee, etc. London: 1883. Printed by Henry Hansard & Son.

"In case of the larger rivers—such as the Rhine, Elbe, Oder, Vistula—the whole river constitutes one district, whose chief engineer is called chief engineer for that river (Strom-Bau-Director). The main office for river and harbor works is a bureau in the department of public works, and is composed of a number of chief engineers (Geheime Bauräthe), under the direction of the Chief of the service (Ober-Bau-Director.) This organization, then, is similar to that in effect in the United States, with the difference, that the chief of the service acts under the Minister of Public Works, instead of acting under the Secretary of War, and that the officials in charge are state civil engineers, instead of being army officers. The further difference, that the districts are again divided into smaller circuits, having a resident engineer in charge, is made necessary, principally from the fact that all existing river and harbor works are kept in good order and condition, and for this purpose demand a constant oversight.

"For such maintenance, an item is inserted in the annual appropriation bill, which is determined from the average of several years' experience.

"The general Government takes the initiative, as a rule, in case of new river and harbor works, upon the reports of its engineers, who make report upon works that are needed. This does not mean to exclude action or agitation in favor of desired improvements by others, be they navigators, merchants, riparian or property owners. But it is the rule that such motions or petitions go first to the engineers who have the district in charge, or to the Government. These projects are then examined, and are pursued further, or are declined. If the parties in interest wish to appeal from the decision of the chief of the service, the Minister of Public Works, they may in form of an appeal bring the matter to the attention of the House of Representatives or of the Senate, through a member of those houses.

"The Minister of Public Works causes plans and estimates to be prepared for those public works which he considers desirable or expedient, and in consultation with the Minister of Finance (Secretary of the Treasury), causes the necessary appropriations to be placed in the estimates for the next year. In case the work is of such a magnitude that several years would be required to complete it, the sum is fixed which may be expended upon it during the first year.

"The annual appropriation bill is presented to both houses of the Legislature, together with the plans and estimates belonging thereto. In discussing this appropriation bill, the Minister of Public Works, or the chief engineer of the service, or the engineers who have had the matter directly in charge, are present, and defend the Government presentation of the subject in committee, no less than in both houses. During these proceedings all proposed amendments and changes are agreed upon. In case such agreement be not reached, the Government engineers withdraw the proposed appropriation item, or else the House defeats the same. In case members of the House present motions for the construction of new works, which the Government has already declined, in answer to parties in interest, a debate or a consideration in committee follows, during which the representatives of the Executive are enabled to give their reasons for having declined to entertain the same. In case the House is

of the opinion that the Executive is in the wrong, it passes a vote that plans and estimates be prepared and presented at the following session. Paying heed to the opinions and demands of popular representation pressed during the proceedings, the Executive is enabled to give the matter further careful consideration, and there usually follows an agreement at the next session. As a rule, the Executive is usually more ready to undertake public improvements than the representatives of the people are ready to grant the necessary funds.

"The House of Representatives may refuse, reduce. or enlarge each separate item of the appropriation bill ; the Senate may only accept or reject the bill as a whole. In case the bill be thus rejected on account of objectionable items therein contained, the bill goes back to the House of Representatives, and the House comes to some agreement with the Senate, similarly to the proceedings in like cases between the Senate and House at Washington, in case of the River and Harbor Bill.

"As I view the matter" (still quoting my learned friend), "the main points of difference between our system and that in vogue in the United States, are as follows :

"1. Demands for river and harbor improvements, whether emanating from the Government engineers or from others, are much more carefully studied, and are presented to the two houses only in case, and in so far as the Executive believes it may be responsible to the country for their cost.

"2. During the debates in the two houses, the members of the Executive branch are present, and take part in the discussions concerning amendments—explaining some points, and disproving, by facts and figures, in the event of untenable requests made in behalf of individual interests.

"3. In case either House takes the initiative for a new river or harbor work, the Executive is charged with the preparation of the necessary plans and estimates, and the project comes up again for action at the next session.

"4. A definite plan of action is established for all large works, necessitating a series of years for their construction, which determines the total amount requisite and the amount to be expended from year to year. In appropriating the sum needed for the year to come, the two houses also approve the whole plan of procedure. They do not, however, thereby deprive themselves of the right to refuse. abridge or enlarge the appropriation as per plan adopted, in any of the years following, in case they deem such a step called for by the circumstances then in effect.

"5. A fixed sum is annually appropriated for the proper maintenance of all existing river and harbor works, which, as a rule, becomes a subject of discussion only in case the usual or average amount be increased on account of a notable increase, in course of time, in the extent of the works to be maintained.

"The whole method of procedure is based upon the fact that in Prussia the Executive forms, with the two houses of the popular representation. a third factor in the Legislative Assembly, having its own well-defined rights and duties."

It is always instructive to "see ourselves as others see us." I therefore give, as a companion picture, what the same engineer has said of

the public works of the United States. In a lecture delivered before the annual convention of the civil engineers and architects of Germany, Aug. 27, 1884, he says:

"I desire to speak on this occasion, in the order given, of the public works, respectively, of the United States as the central Government, of the sovereign single States, and of the cities and towns. In the case of works built by private capital, we shall have to consider railroads navigation canals, owned by private parties and churches.

"The United States Government has in Washington, the capital of the nation, two central departments, which conduct the works of construction that belong to Congress to build or to maintain. These are: A bureau for civil engineering, under the Secretary of War, and another for public buildings, under the Secretary of the Treasury.

"At the head of the engineer bureau stands the chief of engineers, a General in the United States army; at the present time, Gen. John Newton, well known in connection with the submarine operations at Hell Gate, near New York. Under control of this bureau we find:

"1. All the harbor works of the sea coast and on the great lakes.

"2. The improvements of rivers when undertaken in the interests of navigation.

"3. The canals built in connection with the river improvements for overcoming rapids.

"4. Fortifications and constructions of military engineering; of which latter there are so few, however, that the greater part of the work done consists of the first-named constructions.

"This bureau also furnishes a number of officers to other bureaus, to serve as engineers: as, for instance, to the light-house service; to the construction of the Washington monument; for the maintenance of the White House; for statues, and for various city works in Washington, the capital of the nation; also as teachers at the Military Academy, at West Point.

"At the present time, there are in service, under the chief of engineers, 8 colonels, 14 lieutenant-colonels, 26 majors, 32 captains, 26 first lieutenants and 4 second lieutenants; altogether, 110 officers. Only a few of these officers are in regular military service, attached to the battalion of engineers, which at present consists of only 200 men. A few others are engaged in the maintenance of the fortifications and in the torpedo service. The great majority are, in fact, engaged in the same service that with us is performed by the State civil engineers.

"The whole country is divided into districts, which are made larger or smaller, according to the number of works in process of construction within them, each of which has at its head a colonel, lieutenant-colonel or major, and in a few cases one of the older captains. These officers conduct the works within their district, consulting but rarely with any other public authority, and receive their orders directly from the chief engineer, in whose bureau there are three higher officers as division chiefs. The younger captains and lieutenants are assistants of the district engineers.

"It goes without saying that, with the large extent of works in progress, for which about fifteen million dollars were appropriated in

the present year, these officers need a large number of assistants. These assistants are engaged and dismissed according to the necessities of the time being, and according to the means at hand, by the district engineers, so that their position may be said, in general, to be an uncertain one. It is true that, in case of the larger works lasting a long time, many of these assistants have earned for themselves, by industry, technical skill and energy, such a position that they are retained whenever it is at all possible; but, nevertheless, they cannot reckon upon having a fixed position. There are only two U. S. civil engineers in the whole corps, and these were appointed many years ago by an accident of legislation. There are many Germans among these assistants, and in many cases these have won for themselves a highly respected position. Nevertheless, there are few educated engineers among these Germans. Generally they are former army officers, surveyors or manufacturers, who have made civil engineers of themselves in America by force of the positions taken by them. Their per-diem wages are, in general, sufficiently large to support life. Those of superior ability have occasionally a larger income than the officers who command them, whose pay in the higher positions is remarkably small. But the sword of Damocles hovers constantly over the heads of the assistants, and it not infrequently falls, especially when, as was the case in 1883, Congress votes no appropriation for the continuation of the public works, and the only means left to keep them up are the balances remaining from previous years. An employment of former non-commissioned officers of the army on public works is not customary."

(The author next cites several articles he has written, descriptive of various public works in the United States, and reviews, from an engineer's standpoint, the river improvements on the western rivers, building of jetties on the lake harbors, kinds of dredges and pile-drivers used in the United States, canals constructed parallel to the rivers, including the projected Hennepin Canal, which was described by him; speaks also of the light-house service.)

"I come now to the bureau having charge of the construction of public buildings, which, in the United States, is in the department of the Secretary of the Treasury. This bureau erects the custom-houses, post-offices, buildings for the United States Courts, and marine hospitals. All these buildings were in charge of the engineer corps up to the civil war; but at that time, when all the engineer officers were necessarily engaged in the field, an architect was charged with their construction. While the district engineers are almost wholly independent, as far as professional questions are concerned, and the central office rules only upon general and larger questions (especially difficult, technical questions are answered by a commission of higher officers, chosen for that special question); we find, on the other hand, in the construction of the public buildings, the highest type of centralization. The chief of the service causes all the plans and estimates, down to the smallest detail, to be made in his bureau at Washington; he closes all contracts, and merely puts the inspection of the work in charge of some private architect, in the city where it is being built, at a per-diem salary of six to ten dollars. Any changes in design or in detail, which may be found necessary during

the course of construction, must be ordered from the central office. This bureau has change of a yearly expenditure of about five million dollars; its central office, in which the chief architect employs and dismisses all assistants, according to his own views of necessity or propriety, costs about one hundred and fifty thousand dollars annually. Public buildings, dating from the period when the engineering department had charge of their construction, are mostly built in pure Grecian style; since then, the Renaissance has come into power; and in later times, the favorite Queen Anne style, much used in America for private buildings, is used for the smaller public buildings also. Public buildings are erected with great care, as regards perfection of finish and security from fire; the exterior walls generally of granite. Their cost is quite considerable. The Post-Office and Custom House in St. Louis cost, for example, about six million dollars (about sixteen hundred dollars per square meter); the Post-Office and Court House in Philadelphia cost nigh five million dollars (or thirteen hundred dollars per square meter); similar amounts were spent for the public buildings in Boston, Chicago, Cincinnati, Baltimore, and in all the medium-sized cities. The Post-Office in New York cost even more than ten million dollars. In a little city like Albany, the cost amounted to about four hundred dollars per square meter. The mild manner in which an expenditure over the estimates has been handled by Congress is worthy of note. Congress voted in 1870, for example, that the Post-Office building in Boston should cost a million and a half, but the expenditures have amounted to nigh six and one-fourth million dollars; Chicago received an appropriation, in 1871, of four million dollars, but spent also about six and one-fourth million dollars; Cincinnati was to have spent about two and one-fourth million dollars, but the building has already cost five and three-fourths million dollars, and is not yet completed. As regards the time spent in building these works, also, judgment has been very lenient. All the buildings above named were in process of construction at least ten years."

Thus far my German friend. In the Empire of Austria-Hungary, if I am correctly informed, a public work to be paid for out of the Treasury of the general Government must come to that Government on petition from the Government of one of the several states or provinces. It will be observed that both in Austria and Prussia a safeguard is vouchsafed the Treasury of the general Government, in shape of a sort of filter, through which demands upon the Treasury must pass before they can be submitted to the houses of the Legislative Assemblies. In Prussia the corps of state civil engineers, with a Minister of Public Works at the head, forms such a restraining, discriminating body; in Austria it is the Government of the several states or provinces, though I am inclined to believe that it will be found, on further study, that in Austria, also, the corps of state civil engineers perform a service very much the same as that performed by the same corps in Prussia. From what I know of public works elsewhere in Europe, in France, Italy, Holland, and other countries, I believe their organization for the construction of public works to be very similar to the comprehensive system above described.

I was warned by a friend of mine, when I mentioned to him my purpose to write upon the River and Harbor bills of the United States, that

the like "political" subjects had better be eschewed by the writer of papers. I trust I have treated the subject in a manner inoffensive and interesting to the members, to whatever political party each one may belong. I believe that it constitutes one of the dangers of the Republic when vital questions are constantly thought of, and as constantly treated, after the manner of stump oratory, instead of being humbly and diligently studied with a view to seeking wisdom. It is one of its dangers, when the mere current public ear is sought, by our newspapers or by our public men, and upon being found, when it is tickled. It is one of its dangers, when party, sectional, and other kinds of politics are not recognized as such, and are not constantly held distinct and aloof, in the public mind, from a wise, sober, far-seeing statesmanship.

STRENGTH OF SOLID METALLIC ROLLERS TO RESIST CRUSHING.

By J. B. Johnson, Member of the Engineers' Club of St. Louis.

[Read by title, Nov. 19. 1884.]

The strength of solid iron or steel rollers under swing bridges, or under the movable ends of fixed spans, is variously given.

In the Transactions of the American Society of Civil Engineers for 1874, Paper XCII., p. 140, Charles Macdonald quotes from the *Journal of German Engineers* for April, 1874, the following formula :

$$P = \sqrt{\frac{32}{9}\left(\frac{1}{E_1} + \frac{1}{E_2}\right) K^3 l^2 R}$$

where P = total load on cylindrical roller ;
R = radius of cylinder in inches;
l = length of roller in inches;
K = safe compressive stress per square inch.
E_1 and E_2 = moduli of elasticity of the roller and bed-plate respectively.

This may be put in the form :

$$P = \frac{4}{3}\, l \sqrt{2\, K^3 \left(\frac{E_1 + E_2}{E_1\, E_2}\right) R} \qquad (1)$$

Professor Burr gives the equation :

$$P = R\, l \sqrt{2\, K^3 \left(\frac{E_1 + E_2}{E_1\, E_2}\right)} \qquad (2)$$

which is identical with the above, except he has the co-efficient one instead of $\frac{4}{3}$ and R^2 in place of R.

The specifications for the N. Y., P. & O. R. R. give the formula*:
$p = 500 \sqrt{d}$, where
p = load per foot of roller and
d = diameter in inches.
This may be written $P = 42\, l \sqrt{2 R}$ (3)

* Quoted by Prof. DuBois in his *Framed Structures*, p. 342.

In the case cited by Mr. Macdonald we have—

$l = 3\frac{1}{2}$ inches, $R = 1\frac{1}{2}$ inches, $E_1 = E_2 = 29{,}000{,}000$.

$$K = \frac{\text{Elastic limit}}{2} = 35{,}000;$$

whence equation (1) gives

$$P = \tfrac{8}{3}\, l \sqrt{\frac{K^3\, R}{E}} = 13{,}900 \text{ pounds.}$$

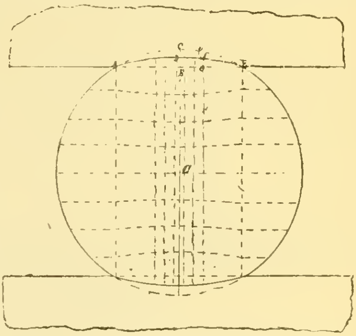
Equation (2) gives

$$P = 2\, R\, l \sqrt{\frac{K^3}{E}} = 12{,}770 \text{ pounds;}$$

while equation (3) gives

$$P = 42\, l \sqrt{2R} = 256 \text{ pounds.}$$

It would seem there must either be a mistake in quoting this formula from the specifications of the N. Y., P. & O. R. R. Co., or else they have the inordinate factor of safety of about 100. If p were the load per lineal *inch* of roller in the formula $p = 500 \sqrt{d}$, it would give a factor of safety of about 8. These rollers were made of steel and did bear a load of 27,270 lbs. each, and turned under this load some 50,000 revolutions before failure. The first two formulæ give, therefore, a factor of safety of about 2. With a larger radius the second formula will give relatively larger results as compared with the first formula.



It is proposed to develop a formula which is rational and which very closely approximates the true character of the strains.

In the figure let C be the center of a cylindrical roller moving between two metallic plates. The roller will be flattened and the plates will be indented. As long as this action is within the elastic limit, it can be computed when the moduli of elasticity are known.

Let the line $A\ D\ B$ be the line of contact between the surfaces. The roller has been compressed from $A\ O\ B$ and the plate from $A\ E\ B$, both to the common line $A\ D\ B$.

On account of the symmetry of the conditions causing distortion on the upper and lower sides of the cylinder, the only undistorted horizontal section is that through the center C. All other sections are distorted as shown in the figure. The distortion will practically disappear at the vertical lines through A and B, because the distorting force has gradually diminished from the middle vertical outward and becomes zero at the outer verticals. On account, therefore, of this gradual diminution in the stress from the center vertical toward A and B, we may conceive the region of the cylinder under compression as made up of a series of independent columns, as indicated by the dotted vertical lines. In this case all shearing action is neglected, and only direct compression con-

sidered. This very much simplifies the problem, and in this case is practically correct.

Let E = modulus of elasticity of the cylinder.
Let E_1 = modulus of elasticity of the plates.
Let p = intensity of stress at any point on $A\ D\ B$.
Let K = equal maximum intensity of stress.
= stress at D.
Let e = distance $A\ E = E\ B$.
Let R = radius of roller in inches.
Let l = length of roller in inches.
Let P^1 = total load on roller one inch long.
Let P = total load on roller of length l.

Since $E = \frac{\text{stress}}{\text{strain}}$ we have

$$\left.\begin{aligned} E &= \frac{K}{\frac{O\,D}{R}} = \frac{p}{\frac{o\,d}{R}} \therefore o\,d = p\,\frac{R}{E} \\ E^1 &= \frac{K}{\frac{D\,E}{R^*}} = \frac{p}{\frac{d\,e}{R}} \therefore d\,e = p\,\frac{R}{E^1} \end{aligned}\right\} \quad (1)$$

$$\text{Whence } o\,e = p\,R\left(\frac{E+E^1}{EE^1}\right) \quad (2)$$

$$\text{or } p = \frac{o\,e}{R\left(\frac{E+E^1}{EE^1}\right)} \quad (3)$$

$$\text{Now } P' = \int_{-e}^{+e} p\,dx = \frac{1}{R\left(\frac{E+E^1}{EE^1}\right)} \int_{-e}^{+e} o\,e\,dx \quad (4)$$

for unit length along the axis of roller.

$$\text{But} \int_{-e}^{+e} o\,e\,dx = \text{area } A\ O\ B\ E$$

$$\therefore P^1 = \frac{1}{R\left(\frac{E+E^1}{EE^1}\right)} \times \text{area } A\ O\ B\ E \quad (5)$$

If this curve $A\ O\ B$ be taken as a parabola, which it may, since $O\ E$ is always very small, compared with R, we will have:

$$\text{area } A\ O\ B\ E = \tfrac{4}{3}\ O\ E \times E\ B.$$

$$\text{But } O\ E = K\ R\left(\frac{E+E^1}{EE^1}\right) \text{ from (2) by analogy,}$$

$$\text{and } E\ B = \sqrt{2\ R\ OE} \text{ for parabola,}$$

$$= R\sqrt{2\ K\left(\frac{E+E^1}{EE^1}\right)}$$

$$\therefore P^1 = \frac{1}{R\left(\frac{E+E^1}{EE^1}\right)} \cdot \tfrac{4}{3}\ K\ R^2\left(\frac{E+E^1}{EE^1}\right)\sqrt{2\,K\left(\frac{E+E^1}{EE^1}\right)}$$

* The length of the compression column in the plates is also assumed to be R.

$$= \tfrac{4}{3}\, R \sqrt{2\, K^3 \left(\frac{E + E^1}{EE_1}\right)} \qquad (6)$$

or, for length l, we have:

$$P = \tfrac{4}{3}\, R\, l \sqrt{2\, K^3 \left(\frac{E + E^1}{EE^1}\right)} \qquad (7)$$

This, therefore, is the formula for finding the resisting power of the roller. It is similar to Prof. Burr's, being obtained on the same suppositions, but with fewer approximations in the solution, and thus coming out with a co-efficient $\frac{4}{3}$ in place of unity.

Any desired value may be taken for K, and if then E, E^1, R and l are known, the value of P is obtained.

From equation (7) we see that the resisting power of the roller is proportional to the radius, instead of the square root of the radius, as in the formula quoted by Mr. Macdonald, equation (1), and also in that used in the N. Y., P. & O. Ry. specifications, equation (3).

For conical rollers use the mean value of R. This follows from the fact that in a cone the radius varies uniformly.*

If steel or wrought-iron rollers are used between bed-plates of similar material, we would have $E_1 = E_2$ (nearly), and they may be both taken at, say, 30,000,000 pounds. Then equation (7) becomes:

$$P = \frac{8}{3}\, Rl \sqrt{\frac{K^3}{30{,}000{,}000}} \qquad (8)$$

If the maximum intensity of pressure be taken at one-half the elastic limit, or at, say, 25,000 pounds for steel and 12,000 pounds for wrought-iron, then equation (8) becomes:

$P = 1{,}930\ Rl$ *for steel rollers and plates,* (9)

and $P = 640\ Rl$ *for wrought-iron rollers or plates.* (10)

If we have steel rollers on cast-iron plates, then $E_2 = 12{,}000{,}000$, and K may be taken as 25,000 for both materials; then

$$P = \frac{4}{3}\, R\, l \sqrt{\frac{2\,(25{,}000),\ ^3\ (42.000.000)}{360{,}000{,}000{,}000{,}000}}$$

$$= \frac{4}{3}\, R\, l \sqrt{3{,}646{,}000}$$

$= 2{,}550\ R\, l$ *for steel roller on cast-iron beds.* (11)

If the rollers are also of cast iron and worked on cast-iron beds, then

$$P = \frac{8}{3}\, R\, l \sqrt{\frac{K^3}{E}}$$

$$= \frac{8}{3}\, R\, l \sqrt{1{,}302{,}000}$$

$= 3{,}040\ R\, l$, *for cast-iron rollers and plates.* (12)

By comparing results (9), (10), (11) and (12), we see that the best com-

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* Prof. Burr, in his treatment, finds for a conical roller that $\frac{L^2 - A^2}{2L} R_1$ must be used in place of Rl in equation (2). Here R_1 is the radius of the larger base, and L and A are the axial distances from the apex of the cone to the larger and smaller bases respectively. Our author was probably unaware that his new co-efficient is equal to $\frac{R_1 + R_2}{2}\, l$, or to the *mean radius* into the length of the roller.

bination is cast iron on cast iron, and the poorest is wrought iron on wrought iron. This results from the fact that cast iron has a low elasticity, that is, it is readily indented, and so distributes the load over a wider surface, while at the same time it has a high compressive resistance. If we could feel sure that our material would not prove treacherous, this combination of cast-iron rollers on cast-iron beds would doubtless give the combination which would bear the greatest load for a given amount of material. On account of the uncertainty in the matter of internal strains in the castings, it probably would be best to have the rollers of steel and the bed plates of cast iron, then this combination gives

$$P = 2550, \ Rl,$$

and we feel sure of the material in the rollers, at least, and these are most apt to fail.

In all the above equations the maximum intensity of the stress on the material was taken at one-half the lowest elastic limit in the combination.

The reason why wrought-iron plates and rollers give so low a bearing power (being only *one-fifth* of cast-iron plates and rollers, and *one-fourth* of steel rollers on cast-iron beds), is on account of this material having a low elastic limit with a high modulus of elasticity. The maximum intensity of stress must therefore be low, and the material is not readily distorted, so that the bearing surface is narrow.

In the case cited by Mr. Macdonald, above referred to, we would have as the bearing power of these several combinations :

Wrought-iron rollers and plates.	$P =$ 3,360 lbs.
Steel rollers and plates..............................	$P =$ 10,130 "
Steel rollers and cast-iron plates........................	$P =$ 13,390 "
Cast-iron rollers and plates	$P =$ 15,960 "

The combination used on that bridge was steel rollers on cast-iron plates, and the actual load on each roller was 27,270 pounds, in place of 13,390 pounds, as given by our equation. That is, the combination was worked up to its elastic limit and failed after some 100,000 impositions and removals of load.

Of course, it is assumed in all this discussion that the fittings are perfect; that is, the plates bear uniformly along the entire length of the roller. For this purpose all surfaces should be carefully planed or turned, and care taken in the erection to bring them all to the proper relative positions.

If economy of material is of less consequence than ease of operating, in case of a swing bridge, then the higher the modulus of elasticity the better, for the more rigid the body, the less it will compress, and the more readily will the rollers turn under their load. For this purpose hard steel rollers and plates should be used.

ORIGIN OF THE WORD TRAMWAY.

By Augustine W. Wright, Member of the Western Society of Engineers.
[Read December 16, 1884.]

The origin of the word tramway is exciting considerable interest at the present time, and our technical journals are devoting not a little space

to this matter. In a recent communication to one of them, I stated my belief that the word was originally condensed from "Trammle." It has been, in my opinion, from ignorance attributed to Outram, the name of an engineer, by dropping the first syllable of his name.

In the Engineers and Mechanics' Encyclopædia, by Hebert, 1838, under the head "Railway," it is stated: "The earliest account we have of the introduction of railways, is in the Life of the Lord Keeper North, from which it appears that about the year 1670 they were made use of at Newcastle-upon-Tyne for transporting coals from the mines to the shipping in the river. These railways were constructed of timber. It is stated by some authors that these wooden rails were subsequently improved upon by making ledges at their sides to prevent the wagons from going out of their tracks ; a form that was subsequently given to them in cast-iron and termed *Tram-plates.* * * * The introduction of cast-iron plates having an upright ledge was originally effected by Mr. Carr at the Sheffield Colliery, about the year 1776."

Wood's Practical Treatise on Railroads was first published in 1825, and has ever since been considered unquestioned authority so far as he goes. He said: "Cast-iron rails, with an upright ledge for the purpose of keeping the wheels upon the line of the former, were first adopted about 1767. In the year 1800 we are told that Mr. Benjamin Outram, an engineer, in adopting this rail on the public railway at Little Eaton, in Derbyshire, first introduced stone props, instead of timber, for supporting the ends and joining of the rails. Mr. Outram, however, was not the first who made use of stone supports, as the late Mr. Barnes employed them in forming the first railroad which was laid down in the neighborhood of Newcastle-upon-Tyne, viz., from Lawson Main Colliery to the river, in 1797."

So far you will notice that his cotemporaries give Mr. Outram no credit for any great prominence that would warrant the application of his name to the "tramways." His only improvement appears to have been the application of stone supports to take the place of timber, *and Mr. Barnes anticipated him in this idea by three years.* January, 1849, the *Civil Engineer's and Architect's Journal* (page 6) contained the following communication : "SIR: In reading the article on George Stephenson, in the last number of the *Journal*, I noticed some errors connected with the description of the Stockton & Darlington Railway which I thought it would be well to point out to the writer of that paper, and to endeavor to correct them as far as I am able. Speaking of the Stockton & Darlington Railway, you say, 'This could hardly be named more than a tramway.' Now, from the very commencement, this line was a veritable railway. It could not properly be called either a tramway or wagon-way. In using those terms, we ought to be careful to apply them according to their proper and genuine signification, or serious errors may eventually creep into our descriptions of works of this class, and which may in course of time become perpetuated and the true meaning of the terms lost. Like railways, those three terms had their birth among the extensive collieries of Durham and Northumberland. The *tramways* are used principally *under ground* for the purpose of conveying the coals from the working district of the mine to the shaft up which they have to be drawn. In

some of the extensive collieries, these tramways will extend for three or four miles. The gauge of the road is about 18 *inches*. The carriage which runs upon this way is a small four-wheeled rolly or tram (hence the term tramway). Upon this carriage is placed the basket containing the coals. Previous to the introduction of tramways and trams, barrows were made for this purpose, the corf or basket being placed on the barrow, and a narrow flagged way for the barrows to run on was laid down, called the barrow-way, which term is even yet in some cases applied to the more modern tramway. It is, perhaps, 150 years since the barrow and barrow-way was superseded by the tram and tramway. * * * The *wagon-way* is used for conveying the coals from the pit to the ships, etc. * * * After wagon-ways came railways. * * * From a long residence in the vicinity and particular acquaintance with the facts, I can vouch for the correctness of my statements." I regret that the above was signed by a *nom de plume* instead of the writer's name. His definitions are corroborated by Smeaton, who, in a report to Lady Irwin, January 27, 1779, on the "Measures of Coals at Newcastle and London," used the following: "And therefore, before the invention of the Newcastle rail or wagon roads, all the coals that were carried down to the ships must have been conveyed on horses' backs." And again: "Since the invention of coal wagon-roads."

The words Tram, Tramway or Railway do not appear in Samuel Johnson's Dictionary. Worcester states in the preface of his Dictionary, 1846: "To the words now added to the vocabulary, and not found in Todd's Johnson, an asterisk has been annexed. Tram and Tram-road are so indicated and defined, the former "A sort of four-wheeled carriage or wagon, a car," and the latter "A road prepared for the easy transit of trains or wagons, by placing on its surface smooth beams of timber, blocks of stone or plates or rails of iron, as wheel tracks. It is a kind of railway adapted for the passage of vehicles with wheels of the ordinary form, for the conveyance of wood, coals, stone, etc. It is also called Tram-way and Truck-way."

Gillespie, in "Roads and Railroads," in 1847, states: "Subsequently these wooden rails were covered with plates of iron; but the introduction of rails wholly of iron seems not to have taken place till 1767. A projection or flange on the outer side of the rails kept the wheels of carriages upon them. They were then called "tramways."

D. K. Clarke in his "Tramways" says: "A tram, according to Nuttall, is the shaft of a cart or carriage. It is also the local name of a coal wagon, whence is derived the compound word '*tram-way*' or tram-road—a road laid with narrow tracks of wood, stone or iron, for trams or wagons."

Knight in his Mechanical Dictionary states: "The name *tram-road* has been fancifully derived from Outram, but comes from tram, a beam, and the trams were the wagons which ran thereon.

Mr. Smiles in his "Life of Stephenson" has the following: "In 1800 Mr. Benjamin Outram, of Little Eaton, Derbyshire, used stone props instead of timber for supporting the ends and joining the rails. As this plan was generally adopted, the roads became known as 'Outram roads' and subsequently, for brevity's sake, 'tramroads.'"

Encyclopædia Britannica, under Railroads, says: "The rapid wear of timber led to the structure of cast-iron to replace the wooden ones, and being limited in width, they were formed with a continuous flange or ledge on their inner edge to keep the wheels on the track. The roads were then called 'tram roads,' having been first laid down, it was said, by Outram, from whose name, omitting the first syllable, the word is said to have been derived. The derivation would apply equally well to the word trammel, the rail flanges being in reality trammels to gauge the road and confine the wheels."

Skeat, in his Etymological Dictionary of the English Language, 1882, states: "Tram, a coal wagon, a carriage for passengers, running on iron rails. A tram is an old Northern word for coal wagon, especially such a one as ran upon rails. There was an act of Parliament for the year 1794 for the construction 'of an iron dram-road, tram-road or railway' between Cardiff and Merthyr Tydvil. * * * About A. D. 1800, Mr. Benjamin Outram made certain improvements in connection with railways for common vehicles, which gave rise to the silly fiction (ever since industriously circulated) that tram road is short for Outram-road, in ignorance of the fact that the accent alone is sufficient to show that Outram, if shortened to one syllable, must become 'Out' instead of 'ram' or 'tram'; beside which, Mr. Outram was not a coal wagon. Yet Brecket's Glossary, third edition, 1846, explains that a tram is the Northern word for 'a small carriage on four wheels, so distinguished from a sledge. It is used in coal mines to bring the coals from the hewers to the cranes.' The word is clearly the same as the Lowland Scotch. Tram (1), the shaft of a cart or carriage of any kind; (2) a beam or bar. This notion is borne out by the cognate Low G. Träam, a word particularly used for the handles of a wheelbarrow or the handles by which a kind of sledge was pushed. Bremm Wörberbach, edition 1771. J. H. Clarke notes that 'the amendinge of the highway or *tram* from the weste ende of Bridgegait in Barnard Castle,' occurs in a will dated 1555. Here a 'tram' probably means a log road."

I trust the foregoing statements will convince you that the so often-accepted derivation of this word "tramway" as derived from Outram is erroneous. You have seen that it was in use two hundred and forty-five years before he introduced the stone props, and I only wonder that the statement attributing the word to an abbreviation of his name has ever been allowed to stand unchallenged and uncontradicted.

The word "trammle," meaning "to confine, to intercept," as defined by Samuel Johnson in 1755, is a very old English word, and I supposed "tram" was derived from it by dropping the last syllable, as the wagons were confined to or interrupted by the tracks; but wheresoever or howsoever the word did originate, it was *not* from Outram.

An attempt has recently been made to induce the American public to use this word tramway in place of street railway, and I, for one, am glad that the American Street Railway Association declined to adopt it. Street railroads for passenger service originated in these United States, were known from their inception as "street railroads," and the word tramway was not applied to them until their introduction into England by George Francis Train in 1860. By all means, therefore, let *us* continue the use of our own designation of street railroad!

AN ORIGINAL METHOD OF FINDING THE LENGTH OF BRACE AND HEIGHT AND HALF-LENGTH OF ANGLE-BLOCK IN A PANEL OF HOWE TRUSS BRIDGE.

By William W. Redfield, Member of the Engineers' Club of Minnesota.

In the panel given, we will assume the following notation: Let l = length of brace, b = height of panel, a = width of panel, c = width of brace, $r = \frac{c}{2}$, m and n represent respectively the half-length and height of the angle-block, β = the angle that r makes with a vertical line. Let us call $\frac{m}{2} = x$, and $\frac{n}{2} = y$, and let x and y be co-ordinates of points of a curve which is the *locus* for the middle point of the line c, and described by a radius-vector r ($= \frac{1}{2}c$), and a varying angle β that said radius-vector makes with b.

To pass from the rectangular to the polar co-ordinates, we have:

$$x = r \cos \beta \,;\; y = r \sin \beta$$

for all possible values of r and β in the panel of the constant width a and height b.

By similar triangles: $m : n :: b - n : a - m$; or, $2x : 2y :: b - 2y : a - 2x$, and $2ax - 4x^2 = 2by - 4y^2$.

$$\therefore\; ax - 2x^2 = by - 2y^2. \qquad (1)$$

Substituting in (1) the above values of x and y we have: $ar \cos \beta - 2r^2 \cos^2 \beta = br \sin \beta - 2r^2 \sin^2 \beta$, and $a - 2r \cos \beta =$

$$b \tan \beta - 2r \tan \beta \sin \beta \,;\; \therefore\; r = \frac{b \tan \beta - a}{2 \tan \beta \sin \beta - 2 \cos \beta} =$$

$$\frac{b \tan \beta \cos \beta - a \cos \beta}{2 \tan \beta \sin \beta \cos \beta - 2 \cos^2 \beta} = \frac{b \sin \beta - a \cos \beta}{2 \sin^2 \beta - 2 \cos^2 \beta} =$$

$$\frac{b \sin \beta - a \cos \beta}{2 \sin^2 \beta - 2 (1 - \sin^2 \beta.)}.$$

$$r = \frac{b \sin \beta - a \cos \beta}{4 \sin^2 \beta - 2} \qquad (2)$$

which is the polar equation of the curve.

Now, if $\beta = 0$, the equation (2) reduces to $r = +\frac{a}{2}$, showing that the brace coincides with the panel, and that $c = a$, $l = b$, and $y = 0$ and $x = r = \frac{a}{2}$.

If $\beta = \left(\frac{a}{b}\right)^{\tan -1}$ (that is, the arc whose tangent is $\frac{a}{b}$), then

$$r = \frac{\dfrac{a\,b}{\sqrt{a^2 + b^2}} - \dfrac{a\,b}{\sqrt{a^2 + b^2}}}{\dfrac{4\,a^2 - 2}{a^2 + b^2} - 2} = \frac{0}{\dfrac{2\,a^2 - 2\,b^2}{a^2 + b^2}} = 0\,;$$

and $c = 0$; $x = 0$; $y = 0$; $l = \sqrt{a^2 + b^2}$, showing that the brace has in this case no thickness and coincides with the diagonal of the panel.

To find the maximum ordinate to the curve, we will resume equation (1):

$$ax - 2x^2 = by - 2y^2. \qquad (1)$$

$$2y^2 - by = 2x^2 - ax. \qquad (3)$$

Differentiating and obtaining, first diff. co-efficient: $4ydy - bdy = 4xdx - adx$; $(4y - b)\,dy = (4x - a)\,dx$; $\frac{dy}{dx} = \frac{4x - a}{4y - b}$.

Put this $= 0 \therefore \frac{4x - a}{4y - b} = 0$; $4x - a = 0$; $x = +\frac{a}{4}$, when y is a maximum.

Substituting this value of x in equation (3), we have $2y^2 - by = \frac{2a^2}{16} - \frac{a^2}{4} = \frac{2a^2}{16} - \frac{4a^2}{16}$, reducing, etc., $2y^2 - by = \frac{-2a^2}{16} = \frac{-a^2}{8}$;

$y^2 - \frac{b}{2}\,y + \frac{b^2}{16} = \frac{b^2 - a^2}{16}$; $y - \frac{b}{4} = \frac{-\sqrt{b^2 - a^2}}{4}$;

$$y = \frac{b - \sqrt{b^2 - a^2}}{4} = \text{value of } y, \text{ when } x = \frac{a}{4}. \qquad (4)$$

To find general value of y in terms of x and a and b, resume equation (3).

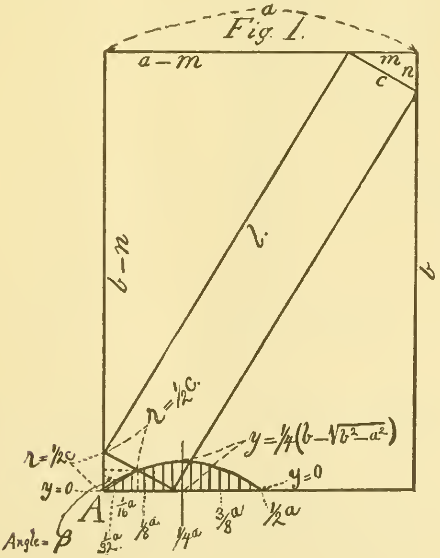
$$2y^2 - by = 2x^2 - ax. \qquad (3)$$

Complete square and reduce, $y^2 - \tfrac{1}{2}\,by + \frac{b^2}{16} = \frac{b^2}{16} + x^2 - \frac{ax}{2} = \frac{b^2 + 16x^2 - 8ax}{16}$;

$$y - \frac{b}{4} = \frac{-\sqrt{b^2 + 16x^2 - 8ax}}{4}$$

$$\therefore y = \frac{b - \sqrt{b^2 + 16x^2 - 8ax}}{4} \qquad (5)$$

Now, if we assume the following values for x, we will see that two values



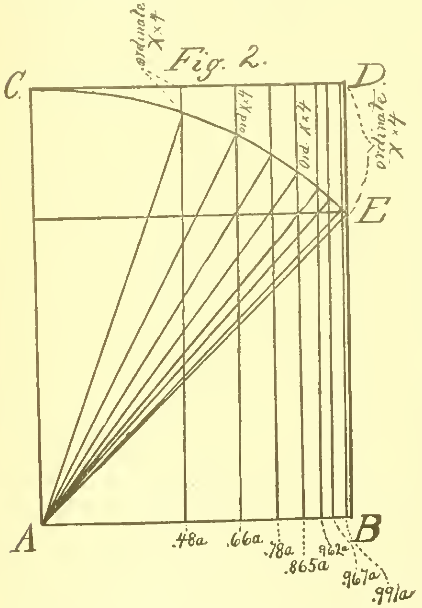
of x equidistant from maximum ordinate give the same value of y; we

also notice that the maximum ordinate is at middle of curve; and that at $x = 0$ and $x = \frac{1}{2}a - y = 0$. All this shows that the curve is symmetrical with reference to its maximum ordinate. The following are the assumptions in accordance with the above:

$x = 0a$ or $x = \frac{1}{2}a$	$y = o$
$x = \frac{1}{32}a$ or $x = \frac{15}{32}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - \frac{15}{64}a^2}\right)$
$x = \frac{1}{16}a$ or $x = \frac{7}{16}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - \frac{7}{16}a^2}\right)$
$x = \frac{3}{32}a$ or $x = \frac{18}{23}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - \frac{39}{64}a^2}\right)$
$x = \frac{1}{8}a$ or $x = \frac{3}{8}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - \frac{3}{4}a^2}\right)$
$x = \frac{5}{32}a$ or $x = \frac{11}{32}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - \frac{55}{64}a^2}\right)$
$x = \frac{3}{16}a$ or $x = \frac{5}{16}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - \frac{15}{16}a^2}\right)$
$x = \frac{7}{32}a$ or $x = \frac{9}{32}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - \frac{63}{64}a^2}\right)$
$x = \frac{1}{4}a$	$y = \frac{1}{4}\left(b - \sqrt{b^2 - a^2}\right)$

We may use the above values for a graphic laying off of the ordinates, as shown in Fig. 2.

Let the figure represent a panel of the height and width b and a: Describe the arc $C\,E$ with the radius $b = A\,C$, or $A\,E$. Lay off on $A\,B =$ the different distances, as obtained from the following:



$$\left.\begin{array}{l} \frac{\sqrt{15}}{8} = .48 \\ \frac{\sqrt{7}}{4} = .66 \\ \frac{\sqrt{39}}{8} = .78 \\ \frac{\sqrt{3}}{2} = .865 \\ \frac{\sqrt{55}}{8} = .92 \\ \frac{\sqrt{15}}{4} = .967 \\ \frac{\sqrt{63}}{8} = .991 \\ 1 = 1.000 \end{array}\right\} \text{ times } A\,B = a.$$

Draw vertical lines across the arc CE to CD. The respective distances from arc CE to line CD measured on the verticals will be the true lengths of four times the ordinates to the curve for the different abscissas $x = \frac{1}{32}a$, etc.; and thus the curve may be quickly constructed. Now, if any width of brace be given, take a radius equal to half the width of brace, and with a center at A (Fig. 1) describe an arc cutting the curve: said point is exact location of center of end of brace; now with same radius describe arcs cutting a and b; these will give corners of the brace or angle block.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ASSOCIATION OF ENGINEERING SOCIETIES.

ANNUAL REPORT OF THE CHAIRMAN OF THE BOARD OF MANAGERS.

To the Association of Engineering Societies:

In presenting the third annual report of the Board of Managers, we deem it a cause for congratulation that the report has been delayed beyond the appropriate time for its appearing, not because the issues of the JOURNAL were behind, or the financial affairs of the Association unsettled on the first of November, 1884; but in order that the announcement might be made of the happy consummation of measures involving the prosperity if not the very existence of the Association.

We believe that the most critical period in the history of the Association has been passed during the last twelve months, and that it is safe to assume that, having survived the dangers of infancy, its prospects of a strong and healthy growth and of a career of great usefulness are excellent.

The Western Society of Engineers—which in the beginning became a member of the Association in the face of a strong opposition, and contrary to the judgment and voice of many of its worthiest and most influential members—voted on the 4th of March last to withdraw from the Association. To enumerate all the reasons which lead to this vote, would be as impossible as it is unnecessary at this time.

While the act of this society in withdrawing—had it been carried out—would not necessarily have been fatal in its results, it would have given the Association a serious backset, from which it could scarcely have recovered for many years, if ever.

This injury has been happily averted—partly through the influence of friends of the Association belonging to other societies that have never wavered in their allegiance; partly through an improvement in the manner and time of issuing the JOURNAL of the Association; but largely, let us hope, through a serious conviction gaining ground that a great loss would have been sustained by the society withdrawing, as well as by the engineering profession in general.

But whatever the causes that have brought about this cheering result, certain it is that on the 16th of December last the vote of withdrawal was rescinded, virtually without opposition, and the Western Society of Engineers continues a member of the Association without having had its relations thereto disturbed for a single day.

This action of the Western Society is not the only thing we have to encourage us.

On the 22d of May, 1884, the Engineers' Club of Minnesota, located at Minneapolis, through its Secretary, made formal application to join the Association. By subsequent action of the Board it was admitted to membership. Mr. George W. Cooley, of Minneapolis, was soon after elected and installed manager for that Club.

On the 16th of December, 1884, the Civil Engineers' Society of St. Paul also voted to make application for membership in the Association. The application having been favorably acted upon by the Board, the society at this writing has been installed a member of the Association. Mr. C. J. A. Morris, St. Paul, Minn., has been appointed a member of the Board by that society. Each of the two societies named has about twenty-six members.

The Engineers' Society of Western Pennsylvania, with a membership of about 280, and having its headquarters at Pittsburgh, having appointed a committee of five to investigate, and report on the question of becoming a member of the Association, has now before it the report of the committee, made December 16th, 1884, which is unanimous in recommending that it join. As the measure is receiving the support of many of the leading members of the society, we may reasonably hope for a favorable vote thereon. But whatever the outcome at Pittsburgh, it is cause for congratulation that

the subject is being discussed. It is a matter of observation that friends for the Association are frequently gained, while none are ever lost by discussion.

About the first of next May five years will have passed since the initiatory steps were taken by the Civil Engineers' Club of Cleveland that resulted in the organization of the Association of Engineering Societies, and on the 13th of June next it will have been four years since the Board of Managers was organized. The first issue of the JOURNAL was in November, 1881. The aggregate membership of the four societies then belonging to the Association was 405. The aggregate membership of the six societies that now belong is 550. Three volumes of the JOURNAL have been published, aggregating 1,006 pages of reading matter.

These are a part of the general record of the Association. Before passing to the specific record for the last year, we desire to review as briefly as possible the objects for which the Association was founded, that we may form an idea of how nearly these objects have been attained, and wherein they have fallen short. We should also, if possible, get our bearings with the outside world of engineering, that we may properly judge of our relations thereto, and the light in which we appear to comparative outsiders.

An editorial article in the *American Engineer*, of November 14th, 1884, under the title of "Engineering Societies," has for a theme the objects and functions of Associations of Engineers in general, particularly in their various phases of organization and development. In the course of this article the editor laments the fact that Associations of Engineers have not been broadly based; that they have limited themselves to narrow specialties; have followed when they should have led; and have too frequently had their policies determined by cabals. "No one," says the editor, "can point with pride to the great American Association of Engineers specialized in sections, and localized in chapters; representative, dignified, a powerful social and political unit, molding public thought, projecting great enterprises, and leaving its impression on legislation." * * * * * * "In foreign countries great centralized bodies have grown up simply for the reason that distance is no bar to occasional attendance at meetings, or the evils of a majority non-resident membership are not seriously encountered. In this country of immense distances this evil early appeared. Its normal correction demands a chapter organization, with a style of government adapted thereto. Sinister council has prevailed, and no remedy appearing, the foundation of Engineering Clubs in every place where twenty could assemble has resulted."

The editor admits that the city clubs have developed a glimmering of an idea in a joint publication, which, pursued to full purpose, might develop the chapter plan.

Some of the judgments of this article may have been hastily formulated, while others are doubtless tinctured with journalistic notions, with which few but professional journalists would agree. But whatever its faults, we believe it to be generally free of undue bias, and that its general conclusions are sound. Coming from the source it does, it is entitled to consideration, and particularly so as the author has had the courage to say aloud what has seldom obtained utterance above a breath.

Being, as we believe, comparatively unfamiliar with the history of the Association of Engineering Societies, the author has naturally failed to grasp the whole truth relative to that Association in the real manner in which it is present in the minds of those better acquainted with its past.

For the sake of historic truth the following summary of facts are here recorded :

That the Association of Engineering Societies, in its present outward form, was not in the beginning considered the highest ultimate achievement to be aimed at, is shown by the preliminary avowal that heads the Articles of Association : "*For the purpose of securing the benefits of closer union and the advancement of mutual interests, the engineering societies hereto subscribing have agreed to the following articles of association.*"

Also by the following from Article 1, under name and object : "Its *primary* object shall be to secure a joint publication of the papers and transactions of the participating societies."

The meeting held in Chicago December 4th, 1880, at which these articles were drawn, was dominated wholly by the idea that nothing should be embodied in the articles that could possibly engender a narrow policy; or that could in any way interfere with a free and full development of the Association in any direction which the future might mark out as desirable. At the same time it was the general conviction that only one step could be safely taken then, and that the *primary* object should be a joint publication. The *secondary* object was no less real because it was omitted from the articles.

It was the avowed determination of the meeting not to attempt the impossible and so far as its power and wisdom would allow, to steer clear of breakers then in sight.

In the discussion that preceded the adoption of the articles of association by some of the individual societies, arguments in the affirmative were largely based upon the broader idea.

In the historical sketch given of the Association, in the first number of the first volume of the JOURNAL, will be found these words :

"The Association has been called into being by no narrow spirit. Many of its promoters believe that local engineering societies should be established and fostered in every centre of population where the engineering profession is sufficiently strong to support one : thus bringing each member within the easiest possible reach of his society. They also believe that these local societies should be brought into affiliation by some Association with a wider sphere of action, by means of which common purposes may be executed, and through which their energies may be stimulated to high professional aims.

"While many have been actuated by this broad spirit, the co-operation of these widely separated societies has been, perhaps, mainly secured through a desire to effect an interchange of professional papers. To this desire the first number of the journal of the Association may be said to owe its origin.

"May we not hope that this act of co-operation is merely the initial stage in the development of an organization from which more than the interchange of papers will be realized, and for which we may reasonably predict a great future.

"We surely indulge the belief that the articles of association were not only begotten in a generous spirit, and are not only founded upon correct principles, but that they possess sufficient vitality and adaptability to permit growth in any direction which experience may indicate as desirable ; that by wise counsel, and the cultivation of a professional *esprit de corps*, an organization will ultimately be evolved from this beginning which will perform a work not now being done by any association in the land ; a work beneficial to the participating societies, as societies, and to every engineer who desires a better tone and higher standing for the engineering profession."

Again, in the second annual report, attention is drawn to the subject by the statement that, "a confederation of engineering societies which would be one in fact as well as in name, should be the outgrowth of the Association."

Indeed it can be truthfully said that your Board of Managers has constantly kept the fuller and broader ideal in view.

If at any time it has seemed to be obscured, it has been because of the necessity of making sure of that which has already been accomplished, by so conducting the affairs of the Association as to place it upon an impregnable foundation, if such a thing be possible.

It is no easy matter to map out a practicable plan for a National Association of Engineers. It is not however difficult to give some of the general characteristics which such an association should undoubtedly possess, and to conjecture some others with reasonable assurance.

Our conjectures—if we may be allowed to indulge the fancy—would run somewhat in this wise :

A National Association of Engineers should be sufficiently comprehensive to gather into its fold all the scattered and diverse elements of the engineering profession, in every branch, which are now struggling for some sort of organization. To do this we must adopt the chapter plan or some one nearly allied to that plan. It would also need to be organized in sections, or groups, which would probably with propriety extend to the various chapters, as well as to the parent, or central, organization. Into these sections, or groups, would be thrown special, or allied branches of engineering.

It would, perhaps, in many respects model its meetings—which would be annual—after those of the American Association for the Advancement of Science. In fact, both in organization, and in the manner of conducting meetings, it would imitate in many respects the Science Association. It would have chapters—corresponding to our local societies in all centres of population where sufficient members could be obtained to support one. These chapters should be quite free, and as nearly independent as consistent with general interests. They would be hampered only by certain broad rules that could be made general in their application.

There would probably be two classes of membership, viz.: Membership in the

central society, and membership in the chapters to which different qualifications woul be attached. That in the chapters at least would be probably as broad as that to any of our local societies. This National Association would imitate the Association of Engineering Societies in publishing monthly the matter furnished by the various chapters or sections. To this publication would probably be superadded an annual publication containing the proceedings of the annual meeting and the papers read thereat. These are mere suggestions covering a few of the features that it seems to us a national association should possess.

Is the dream of such an association Utopian? Some will say yes, though we believe it is not. That it may be slow in taking shape, all will readily admit. There are so many special and conflicting interests that must be removed or harmonized; there is so much inertia to be overcome in the engineering profession, and particularly in older and stronger societies, that we need not be surprised to find it a matter of slow growth.

Can the American Society of Civil Engineers, the American Society of Mechanical Engineers, the Institution of Mining Engineers, the Civil Engineers' Club of Philadelphia, and other similar associations, be induced to practice sufficient self-renunciation to make such a thing possible? What the answer to this question will be, time alone can tell; we will not presume to conjecture.

These propositions alone are clear:

1st. In a country so vast as this, with such unlimited industrial capacity, that is destined to have a population of 100 millions in a comparatively short time, no association can be considered national that does not cultivate local societies or chapters of some kind, and make itself broad enough to embrace all branches of engineering science and practice.

2d. Until the older and stronger societies can have the fortitude to co-operate with each other, and with the Association of Engineering Societies, either in the formation of a new organization upon a more liberal basis, or in remolding an existing one to meet the requirements, the Association of Engineering Societies will remain the nearest approach to a national association possible.

3d. Such being the case, it should be fostered, strengthened and broadened in every possible manner, as the forerunner of better things, as the one bond of unity, to fraternize and educate the disjointed fragments of the engineering profession and hold them in readiness to aid the larger organization in its advent.

For these reasons as much as for the passing benefits—which are not to be ignored—do we urge upon you and engineers generally the importance of maintaining the Association of Engineering Societies in a liberal state of expectancy.

Indeed, the time may have arrived when a move in the direction of a closer union among ourselves would be opportune. Should the Society of Western Pennsylvania, with its 280 members, be added to our list, it will certainly entitle us to take a leading position upon this or similar questions, should the several participating societies favor the proposed move, whatever it may be.

A meeting of the Board of Managers was held in New York on September 4, 1884, the minutes of which were published in No. 12 of vol. III.

In the same issue was printed an announcement of one of the principal measures decided upon by the Board at that meeting, viz.: The purpose of publishing in the Journal an index of fragmentary engineering literature, such as reports, engineering papers, etc. In explanation of this move, it may be said that it only carries out, in one form, a purpose contemplated by the Articles of Association, which was to be instituted by the Board at such time as it should consider proper. It may also be said that it is resorted to in the hope of being able to at least partly accomplish a work which is in great need of being done by some one. The various fields of engineering science and practice are rapidly enlarging, and the channels multiplying through which these find publicity. Most engineers are wholly unable to obtain or examine these numerous sources of information, that they may cull from the mass, the matter of service to them in their work. Hence those who are trying to keep abreast of the profession in their several specialties, will appreciate any means that will enable them to gain an idea of current American engineering literature of this fragmentary character. From the list that will be published every month, each person can select those items of special interest to himself, and preserve them in such manner as he may desire. Or he may arrange the whole year's issue at the end of the year in alphabetical order, to be bound with the volume or not, as he may choose. As they are to appear every month, it is, of course, impossible to carry the alphabetical arrangements beyond the

month s issue. To facilitate the preservation of the indexes to suit the individual reader. they are to be printed on but one side of the paper. No attempt will be made to index literature now in existence, except such as is very recent, nor to index decidedly technical documents, of interest only to a special few, who are probably already in possession of the matter itself.

The object of the Board in preparing this Index, is therefore not so much to furnish a complete index of all engineering literature, as to place before the readers of the JOURNAL such papers and reports of value as might otherwise escape them. It is expected to be more than a mere compilation of titles, as the title is usually to be followed by a descriptive note conveying some idea of scope and value.

This indexing, of course, involves a good deal of exacting labor, and could not have been attempted, had not Prof. J. B. Johnson, of Washington University, the member of the Board for the St. Louis Club, volunteered to do it as a labor of love. He is better enabled to do it than others, as he finds that the research involved is somewhat in the line of his professional duties.

There has been no change in the personal of the Board, or of its officers, since the issue of the second annual report, except that due to the admission of the Engineers' Society of Minnesota and the Civil Engineers' Society of St. Paul, which has already been noted.

There have only been nine issues of the JOURNAL during the year, the first six numbers having been consolidated into three issues. This was done in pursuance of the policy adopted last year, because of a deficiency of material for a monthly issue.

For the last seven months there has been no dearth of matter, and the indications are that there will not be soon.

The Board had 2,000 copies of No. 12 of vol. III. printed and liberally distributed among members of societies not belonging to the Association.

At the end of volume III. of the JOURNAL, the number of copies taken by the severa societies was as follows :

Boston Society of Civil Engineers	120
Western Society of Engineers	136
Engineers' Club of St. Louis	111
Civil Engineers' Club of Cleveland	130
Engineers' Society of Minnesota	27
Total	524

At the end of the second volume it was 460, a gain of 64.

During the year assessments to the amount of $2.50 per copy have been levied and collected in two installments of $1.50 and $1 respectively.

The expenditures of the Association for vol. III. are as follows :

Composition, press work, paper, binding and mailing	$998.63	
Engraving	360.97	
Miscellaneous expenses	176.71	
Postage	45.87	
Salary of Secretary	262.53	
		$1,844.71
Receipts :		
Cash balance	$254.25	
Boston Society of Civil Engineers	288.00	
Western Society of Engineers	338.00	
Engineers' Club of St. Louis	229.20	
Civil Engineers' Club of Cleveland	320.50	
Engineers' Club of Minnesota	37.00	
Advertising	271.75	
Sales and subscriptions	75.25	
		1,814.25
Leaving a deficiency of		$30.46
There was due for advertising		$259.25

Up to the end of volume III. assessments aggregating $9.00 per copy, distributed among the several societies, in addition to the entrance fees, have been paid. Credited to the societies, the amounts are as follows :

	Entrance Fee	Assessments.	Totals.
Boston Society of Civil Engineers	$44.00	$1,004.00	$1,048.00
Western Society of Engineers	63.00	1,245.50	1,308.50
Engineers' Club of St. Louis	31.00	688.50	719.50
Civil Engineers' Club of Cleveland	42.50	957.50	1,000.00
Engineers' Club of Minnesota	13.00	24.00	37.00
Totals	$193.50	$3,919.50	$4,113.00

The average number of copies of the JOURNAL taken by the societies for three years is 433, which makes the average cost to the societies per copy per volume $3.16, without allowing for the deficiency, the amount due for advertisements, or extra copies of the JOURNAL on hand. This cost is exactly the same as at the end of vol. II.

If we consider the copies of the JOURNAL on hand as assets, these would have stood on the first of last November as follows:

12 sets of Vol. 1	$3.00	$ 36.00	
135 " " " 2	2.50	337.50	
145 " " " 3	2.50	362.50	
Advertisements due		259.25	
			$995.25
Less deficiency			30.46
Total assets			$965.79

The increase over last year of the amount charged to miscellaneous expenses in the financial statement, is largely due to the expense of the meeting of the Board of Managers held in September.

Respectfully submitted on behalf of the Board of Managers,

BENEZETTE WILLIAMS, Chairman.

CHICAGO, Jan. 12, 1885.

ENGINEERS' CLUB OF ST. LOUIS.

DECEMBER 17, 1884:—The Club met at Mercantile Club at 8 P. M., thirty-five members being present. The reading of the minutes was dispensed with, as they had been printed and sent to all members. They were approved as printed.

The report of the Executive Committee on the canvassing of the letter ballot for officers for the ensuing year was read. The vote stood as follows:

For President, Robert Moore, 45; C. M. Woodward, 22.

For Vice-President, Robert E. McMath, 67; W. B. Potter, 2.

For Secretary, T. D. Miller, 65; Howard Constable, 1; F. H. Pond, 3.

For Treasurer, M. L. Holman, 69.

For Librarian, J. B. Johnson, 69.

For Directors, C. M. Woodward, 46; F. H. Pond, 11; T. J. Whitman, 47; Robert Moore, 4; Theodore Allen, 14; Howard Constable, 12.

The President declared Messrs Robert Moore, *President;* Robt. E. McMath, *Vice-President;* T. D. Miller, *Secretary;* M. L. Holman, *Treasurer;* J. B. Johnson, *Librarian;* C. M. Woodward and T. J. Whitman, *Directors*, as duly elected.

Messrs. Potter, Flad and Pond were appointed a committee and escorted the newly-elected President to the chair.

Committee on printing reported with copies of the new Constitution and By-laws, and were discharged.

The Secretary was instructed to mail copies of the Constitution and By-laws to the members.

Retiring President Woodward read an address, giving a sketch of the life and works of the late Prof. C. A. Smith.

The resignation of Mr. Jos. Hill was read and accepted. The following gentlemen were proposed for membership: J. C. Meredith, by J. A. Sedden and H. W. Baker; O. L. Petitdidier, by J. A. Sedden and H. W. Baker; S. F. Burner, by M. L. Holman, Ed. Flad and C. M. Woodward; Geo. A. Brown, by J. B. Johnson and C. C. Brown; T. G. Lansden, by J. B. Johnson and Jno. Sobolewski; J. B. Clements, by Hubert Taussig and Carl Gayler.

A paper by Mr. J. A. Ockerson, entitled "The Earlier Floods of the Lower Mississippi," was read by Mr. J. B. Johnson, and was generally discussed.

Mr. J. B. Johnson then read a paper on the failure and collapse of the large gas-holder of the St. Louis Gas-Light Co. General discussion followed.

[*Adjourned.*] THOS. D. MILLER, Sec'y.

JANUARY 7, 1885 :—The club was called to order at 8 o'clock by President Moore, thirty-five members and six visitors being present.

The minutes of the last meeting were read and approved. The report of the Executive Committee was read and approved.

The following gentlemen were unanimously elected members of the Club : A. P. Man, W. L. Breckenridge, J. C. Meredith, O. L. Petitdidier, S. F. Burnet, G. A. Brown, T. G. Lansden and J. B. Clements.

The President appointed the following committee on *Smoke Prevention :* Prof. Wm. B. Potter, chairman ; Messrs. W. H. Allderdice, Theodore Allen, H. Constable, F. H. Pond and C. E. Jones.

Mr. J. B. Johnson stated that the St. Paul Engineers' Club had been admitted to the Association of Engineering Societies, and that the Engineers' Society of Western Pennsylvania, of Pittsburgh, were considering the question of joining the Association.

On motion the Secretary was instructed to communicate with the members of the Club, and ascertain the number desiring membership in the Mercantile Library for the ensuing year.

Mr. C. W. Clark was proposed for membership, recommended by Messrs. J. A. Ockerson and Robt. E. McMath.

Mr. Jno. A. Sobolewski read a paper on "Economy in Gas-Engines." In the general discussion which followed, he said that the economy consisted in the absence of skilled labor, the cleanliness of the machines, the ease with which they are started, and the absence of risk from fire ; also that the gas bills were ninety-nine per cent. of the cost of operation.

Mr. C. T. Aubin read a paper on "Protection Against Fire and Means of Extinguishing Same."

On motion, the privilege of the floor was extended to Mr. H. Clay Sexton, Chief of Fire Department. He thought many of our large buildings were built for nothing but to burn down, that the extent of some of our fires was not the fault of the firemen, but the fault of the men who construct the buildings, and the carelessness of those who occupy them.

General discussions followed.

Moved, that a committee of five be appointed to investigate the matter of indicating the location of fire-alarm boxes by colored glass in the street lamps, or otherwise, and report at the next meeting.

It was thought that the question was not in the province of the Club, and the motion was lost.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JANUARY 6, 1885 :—The 200th meeting was held at 4 P. M., President Cregier in the chair.

The minutes of the last meeting were read and approved.

Upon ballot the following gentlemen were elected Members : Charles P. Matlack, City Engineer, San Antonio, Texas, and Ralph E. Brownell, City Engineer, Lake, Illinois.

Mr. Williams, Manager for this Society in the Association of Engineering Societies, presented a bill, which was ordered paid, for $1 a copy on each number of the JOURNAL taken by the Society, amounting to $136.

Mr. Liljencrantz read a letter from the publisher of *Engineering* to the effect that this journal would be furnished free to the Society for the year 1885. A vote of thanks was passed to the publisher of *Engineering*.

On motion of Mr. Wright it was voted that the President to be elected at this meeting be requested to revise the Standing Committees of the Society.

The Secretary presented a letter of resignation from Mr. Greeley, giving certain reasons for withdrawal.

It was voted that Mr. Greeley's reasons were not satisfactory and that his resignation be not accepted, and that the Secretary be instructed to request him to withdraw it.

The resignation of Mr. R. E. Farnham was read and accepted.

The Annual Report of the Secretary was read and afterwards accepted and approved.

Upon ballot for officers the following were elected :

President, Benezette Williams ; *First Vice President*, Octave Chanute ; *Second Vice-President*, Samuel McElroy ; *Secretary*, L. P. Morehouse ; *Treasurer*, Charles Fitz Simons ; *Librarian*, G. A. M. Liljencrantz ; *Trustee*, A. W. Wright.

President Cregier made a brief address, after which the meeting adjourned.

L. P. Morehouse, Secretary.

Note.—Minutes for December 2, 1884, as printed, should be corrected to show application for membership by Mr. Ralph E. Brownell, Chief Engineer Town of Lake, Ill., endorsed by Messrs. Randolph, Cregier and Wright.

ANNUAL REPORT OF SECRETARY FOR YEAR 1884, PRESENTED JANUARY 6, 1885.

During the year 23 meetings have been held and 19 papers have been presented, as follows:

1. The Rasmusen Cable System, as applied to Street Railways, by A. W. Wright.
2. Lateral System for Iron Pratt Truss Highway Bridges, by J. A. L. Waddell.
3. Electric Motors, by A. W. Wright.
4. Track Problems, by A. W. Wright.
5. The National Electric Signal, by Isham Randolph.
6. Location of the Northern Pacific Railway Across the Rocky Mountains, by I. C. Chesbrough.
7. The Weehawken Elevator, by W. H. Lotz.
8. A Problem in Curves, by A. W. Wright.
9. The Proper Sub-Division of a Full Government Quarter Section, by Z. A. Enos.
10. Memorial, G. Burt Lake, by the Secretary.
11. Duty Test of a Cast Iron Boiler, by W. S. Bates.
12. New Union Passenger House of Chicago & Western Indiana Railway Company, by Isham Randolph.
13. Stable Construction, by A. W. Wright.
14. Gaseous Fuel, by John Zellweger.
15. Street Railway Joints, by A. W. Wright.
16. Memorial, Alexander Wolcott, by E. A Fox.
17. An Interlocking Switch and Signal Apparatus, by Isham Randolph.
18. Compressed Air and other Systems for Propulsion of Railway Cars. (Discussion.)
19. The Origin of the Word "Tramway," by A. W. Wright.

The following named gentlemen have been admitted to membership :

Ferdinand Hall [Associate], George E. Palmer, George R. Bramhall, John A. Porter, William O. Winston, John Saltar, Jr.

By direction of the Society, a circular dated February 8, was issued, requesting members to send each an autobiographical sketch on a printed form, in response to which 46 replies have been received. It is for the Society to determine what use shall be made of the interesting material contained in these papers. Members who have not yet filled out these forms will be reminded by this notice of their delinquency in this respect.

In answer to the circular of April 7, requesting photograph likenesses, 17 photo-

graphs have been received. A handsome album has been purchased, and it is hoped that each member who has not already sent his picture will forward it, without delay, to complete the collection.

Several amendments to the Constitution and By-Laws have recently been made, all with a view to enlarge the scope and add to the efficiency of the Society.

The question of remaining a member of the Association of Engineering Societies has been thoroughly and warmly discussed, but the present sentiment appears to be nearly unanimous that we should retain our connection with the Association.

The total amount paid by us to date to the Association comprises the following sums :

In the year 1881	$63.00
" " 1882	483.00
" " 1883	210.00
" " 1884	549.50
Total	$1,305.50

This is for, say, 130 copies for 3 yearly volumes.

From the financial statement following, it will be seen that the expenses for the year have been much larger than ever before. This is partly owing to the fact that, for the first time, we pay rent for our rooms. Some expenses of the year will not be repeated, but it would appear that we should provide a revenue of about $1,200 for the coming year.

As the revenue this year amounted to only $1,003 it will be necessary to devise means to raise the additional amount required.

Receipts and expenditures are as follows :

Cash on hand per last report		$533.19
Received for annual dues	$898.00	
" " entrance fees	105.00	
" " furniture	45.00	
		1,048.00
Total		$1,581.19
Paid for rent	$360.00	
" " janitor, gas, etc	25.87	
" " library	158.88	
" " printing proceedings, etc	147.75	
" " postage and stationery	69.80	
" " entertainment of Am. Soc. Mining Engineers, etc	39.25	
" " membership in Association	549.50	
" " portraits	129.00	
" " furniture	88.30	
		1,568.35
Balance in hands of Treasurer		$12.84

L. P. Morehouse, Secretary.

January, 6, 1885.

January 20, 1885 :—The 201st meeting was held at 4 P. M.

Vice-President Randolph introduced President Williams, who delivered an inaugural address.

The Secretary having arrived, the minutes of the preceding meeting were read and approved. Mr. Wright, for Committee on Transportation, announced a paper for the next meeting, "Ventilation of Stables."

It was voted that the Committee on Portraits have the portrait of President Williams added to the collection of Presidents' Portraits.

Mr. G. R. Bramhall read a paper "What Civilization owes to the Architect and Engineer."

It was voted that the address of the President and the paper by Mr. Bramhall be printed.

[Adjourned.] L. P. Morehouse, Secretary.

INAUGURAL ADDRESS OF PRESIDENT BENEZETTE WILLIAMS TO WESTERN SOCIETY OF ENGINEERS, JANUARY 20, 1885.

Gentlemen of the Western Society of Engineers:

In sincerely thanking you for the confidence manifested by the Society in electing me to the office of President, I must confess to a degree of diffidence in presuming to accept a chair that has been so well and so honorably filled by the half-dozen distinguished gentlemen whose portraits adorn our walls.

All of these gentlemen are now living; two of them in other cities and four of them call Chicago their home. But one of the six is with us to-night. Ill health, advancing years, and absence from the city account for their vacant places. It is with profound sorrow that we all must observe the changes that this denotes. It does not merely indicate that some of these worthy predecessors have removed from Chicago, and that others have laid aside life's active work; it means that we, too, will soon give place to others—that our work, whether it be of a permanent or of a transient nature, will soon be a thing of the past. If it be permanent, it will form one stone in an enduring edifice; if transient, the next generation will be as if we had not met here to-night.

Such thoughts suggest the queries: What purpose did the founders of this Society have in mind? What was the object aimed at by them? Why do we meet here, month after month, as it were, from an impulse which we cannot resist? To be plain, what is the real object of engineering societies? Such questions are more easily asked than answered. If we turn to our constitution, we find that it answers by saying, "The advancement of the science of engineering and the interests of the profession."

The constitution of the American Society of Civil Engineers says that "its object shall be the professional improvement of its members, the encouragement of social intercourse among men of practical science, the advancement of engineering in its several branches, and the establishment of a central point of reference and union for its members." Substantially the same reason for its being is given by every engineering society whose constitution it has been my lot to examine. Such concurrence of testimony ought to be sufficient to establish the general truth of the answer.

When it comes to the means to be employed to attain the object, there is equal agreement, and the answer of one constitution is the answer of all. In the language of our own, the means "shall be periodical meetings for the reading and discussion of scientific papers and matters of scientific interest, the collection of a library, and the publication of such parts of the transactions as may be deemed expedient." It is thus seen that the object of engineering societies generally and the means prescribed to attain that object do not vary materially from New York to San Francisco.

Where there is such apparent unity of purpose and of method, the questions arise, Why should there not be entire co-operation and a community of benefits among engineering societies of every kind, and in every place? Why is there not a centralization of interests that are or ought to be common to all, instead of differentiation in all things? As the cause of this state of affairs lies as, I believe, in the wrong application of methods

which are proper enough in their places, so its remedy is to be sought in discriminating between things that differ, and in the application of methods within their lawful limits.

While, as has been seen, all engineering societies have the same object, and propose the same or like methods, only a few of the methods are of universal application. Other methods, such as frequent meetings and reading of papers, intimate social intercourse, the collection of a library, maps, drawings and models, are creatures of locality; close proximity to the societies' headquarters being necessary to render such methods available.

Such being the case, no society with a small portion of the geography of the United States as a basis, can make a success of spreading itself over any wide range of territory. Efforts of this kind must always prove a failure in so far as elements dependent on locality enter into its being. These will ever confront it with the positive avowal, that thus far thou shalt come and no farther. We know that such a society may grow and prosper, when hampered by limiting elements, even beyond its natural boundaries. It may have a large and increasing non-resident membership; it may, like the American Society of Civil Engineers, number its members by the hundreds; but these things do not change the fact that it is essentially local, and that it is acting under all the limitations that belong to a provincial organization. It does not change the fact that it is trying to live under conditions, and within an environment. to which it is not adapted.

That this view is a correct one, the formation of ten or twelve societies and clubs in the leading cities of the country, besides New York, and their present flourishing condition, incontestably proves.

To speak plainly, while the objects of the American Society are broad, and its methods good within certain boundaries, it is impossible to extend them outside of those boundaries with profit. There is a work as extended as the English language on this continent, which should be done by some organization. This work consists in drawing together all the scattering engineering societies of America, and welding them into a harmonious whole. The office of such an organization would not be to fill the field that they occupy, any more than the office of the Federal Government is to fill the fields of our State governments. Barring the divisions on lines of the various branches of engineering, there is absolutely no difference between the several engineering societies of the country, except in size and in name. The Denver Society of Civil Engineers is just as well adapted to become a national society as any other one. We all have constitutions good enough in themselves, but of such a character that each is essentially a rival of another.

A national association will confederate, and not rival, the other societies. A national association will make the objects and methods of universal application common to all, and will provide that those of a provincial character—that are dependent on locality—shall be turned to account by the individual societies within their own domains.

A national association will foster and encourage local societies as the groundwork of its strength. instead of fearing them as the despoilers of its heritage.

If the objects for which we meet here are worthy ; if the advancement of our profession, and through it the general good of our country and of our race, are important enough to claim our best efforts, then certainly we should not hesitate to take such steps, to make such sacrifices, as will most contribute to the general good.

The effort to establish the Association of Engineering Societies during the last four years, and particularly the part that this Society has played therein, is fresh in the minds of all. The primary object of this Association, as stated by the Articles of Association, is to secure a joint publication of the papers and proceedings of the several societies. Many of you will remember, however, that from the first, and in the arguments before our Society, its importance has been urged upon the grounds of its being a half-way house to a more perfect organization.

Our Secretary particularly will remember that this object was avowed in the meeting at which the Articles of Association were drawn. He will also remember that it was the desire of every one to make haste slowly, and not to venture into deep water until the ability to swim in shoal should be made manifest. All of you will remember that, in season and out of season, I have used my best endeavor to maintain our Society's relation to the Association ; and I particularly remember, with the greatest gratification, the generous manner in which the Society, in its last act, renewed its allegiance to the Association.

Speaking as a member of this society, without attempting to voice the opinion of others, I can say that I believe some steps ought to be made to bring about a more thorough alliance than is afforded by the Association in its present form.

There is perhaps no one who would not be rejoiced to see the oldest and strongest society initiate a policy that would lead to the formation of a National Association such as would be large enough for our country; but judging from the past there seems to be little hope of this. Indeed, the time may not be ripe for such an idea to be adopted anywhere.

Such ideas may be deemed chimerical by many, though to me their triumph at no distant day is exceedingly probable. They may seem to be brought too soon upon the stage, though such will always be the case at first glance, let their appearance be when it may. They must have time to win a hearing and still more, perhaps, to win general favor. The sooner their advent, however, the easier their triumph. I believe that our own society should hold itself in readiness to take advanced grounds, and should be willing to consider and advise upon propositions looking to the formation of such an association, let the propositions come from what source they may.

These thoughts have become convictions to me, and hence I beg your indulgence in giving them expression. If I have seemed to give them undue space, to the exclusion of other society questions, it is only because the other questions have largely been answered in the working of our organization. They have become a part of our daily routine, as it were. Not that they are unimportant by reason of this ; but, being the most important, they have had the first attention, and can be trusted to take care of themselves, by dint of occasional urging with whip and spur.

I trust that in the year that has just begun our society may make record of useful work second to that of none that is past. Let us go forward in the course in all modesty, but with a determination to equal, and if possible to excel, our best achievements; but "let not him that girdeth on his harness boast himself as he that putteth it off."

CIVIL ENGINEERS' CLUB OF CLEVELAND.

DECEMBER 9, 1884:—Regular meeting held, President Holloway in the chair.

In the absence of the Secretary, Mr. S. J. Baker was elected Secretary *pro tem*

Minutes of last meeting were read and ordered corrected so as to read that the resolution of Mr. Swasey, in reference to papers read before the Club, first appearing in the JOURNAL of the Association, before being published in other technical journals, be referred to a special committee to be appointed by the Chair, instead of to the Committee on Library and Publications.

The minutes were approved as corrected.

Upon the recommendation of the Committee on Membership, Messrs. Chas. W Fenn, Geo. W. Goetz, Chas. T. Sweet and Newton M. Anderson were elected to active membership in the Club.

On motion of Mr. Paul, the Committee on Library and Publications was authorized to have bound not to exceed 10 sets of the completed volumes of the JOURNAL of the Association.

Mr. Alex. E. Brown read a paper, entitled "The Rapid and Economical Handling of Bulk Materials, Especially Coal and Ore." Mr. Brown's paper was illustrated by an ingenious model and by numerous drawings, and was very generally discussed.

[*Adjourned.*] S. J. BAKER, Secretary *pro tem.*

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

BRIEF SANITARY MATTERS IN CONNECTION WITH ISOLATED COUNTRY HOUSES.

BY E. W. BOWDITCH, MEMBER OF BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read April 16, 1884.]

I am unable to tell you what is generally considered the best practice, for I am not sure there are any definitely established rules; therefore I can only explain *my* ways of doing such work, which, though I try to make as complete and at the same time as simple as possible, I know to be far from perfect.

Plumbing and drainage work has grown up unconsciously with my landscape gardening, and not finding any texts or practice that seemed wholly satisfactory, I have been forced to devise new arrangements from time to time, according to the requirements of the case in hand.

To give all the details of house plumbing this evening, or any *one* evening, would be impossible, for lack of time, and not worth while even if there was time, as much of it would prove matter of little or no interest. I will confine my remarks therefore to certain elements of the work where my practice differs, I believe, essentially, from that of most engineers, and where perhaps my experience, if of no assistance to other members of the Society, may excite their friendly criticism in such a way as to help me.

There are two kinds of country places that I am liable to be called upon to prescribe for:

First. A new place where nothing has been arranged.

Second. An old place where the occupants have been troubled either by their outside arrangements or by fixtures or pipes within.

Under the first head let us suppose a small tract of perhaps two acres of land in some inland town, where the family intends to live but six months in the year, though they are liable to reside there the whole twelve.

There are no sewers and no public water. The soil is a stiff, retentive clay, rather wet in spring. The desire is expressed to have plumbing and drainage that shall be as inexpensive as possible, but that shall be entirely safe.

In considering the arrangements inside the house, I find myself in the same predicament as the French surgeon, a specialist upon setting the bones of the arm, who, when a patient was brought him with his right arm broken, expressed his sorrow at being unable to be of assistance, as his specialty was the left arm.

I have endeavored to post myself thoroughly upon house plumbing, but confess to only knowing partially about the wastes ; the supplies I do not feel competent to pass upon.

One class of annoyance caused by plumbing, perhaps the principal one, is due to the soil pipe or some of its fittings.

Second quality of iron, poor hanging, insufficient calking, careless mechanics, putty, cement, rag or paper joints—all these and a dozen other things are liable to be sources of trouble. Subordinate wastes are apt to be annoying, occasionally, too, to a less extent.

The mechanical work can always be superintended, and within certain limits may be made secure and tight ; not so easy, however, with the materials.

There is seldom a valid excuse for ever making waste pipes, within a building, of anything but metal.

Earthern tile is frequently used ; also to a limited extent, brick, stone, and wood : twice I have found canvas—all these, however, are inferior, and should never be accepted or specified. The writer believes that at the present time, hereabouts, lead and iron are more used for wastes than any other materials, and are found the most satisfactory on the whole.

One or two arrangements, relative to the wastes, I have made use of, that are not, so far as known, in general use, and that may not be the best, though they have served me many good turns, and I have not succeeded in devising any better.

Soil pipe, as it is usually put in, is apt to be of cast iron, four inches in diameter, and is known in the market as "heavy" or "extra heavy." For some years the tar-coated or black enameled pipe has been the favorite, as being the more reliable, the writer in common with others making use of the same freely, until one day a cracked elbow, tar coated, was detected. Since that time plain untarred pipe has been specified and subjected to the so-called kerosene test, which consists of swabbing out each pipe with kerosene or oil and then allowing it to stand for a few hours. A moment's thought will convince any one that when a pipe is asphalted or tar coated, it is very difficult to detect either sand holes or small cracks, and the difficult of proper calking is increased, as lead does not cling so well to the tar as to plain iron.

At present, the kerosene test, so far as the writer is concerned, is a misnomer, because raw linseed oil is used exclusively as giving more satisfactory results, and being less troublesome to apply.

I have here a length of the ordinary "heavy 4" commercial soil pipe, plain, and selected at random. Yesterday noon I had it oiled at my office, in order to be ready for to-night, and you see by the chalk marks

I have made, just where the leaks were and their area. I may say here that a sound pipe of this calibre and standard weight is the exception rather than the rule, and it was selected for this experiment merely to try and show the reaction a little better than the heavier pipe might.

Experiments of this nature I have carried along for the past two years, and I am glad to say that, since I began, the quality of the soil pipe furnished by the dealers for my work seems appreciably better than at first. Whether the poorer pipe is still made and sold to other customers I have no means of knowing ; probably it is, however.

A large quantity of the pipe is now being tested at my suggestion by the Superintendent of Construction of the Johns Hopkins Hospital, at Baltimore. I have not yet heard the results from him, but doubtless they will be interesting. A brief summary of the results may be of some interest.

The different makers of soil pipe generally used by plumbers hereabouts are :

Mott & Company, Abendroth, Blakslee, Dighton, Phillips & Weeden, and Bartlett, Hayward & Co.

On 4″ extra heavy pipe my results have been as follows :

Percentage passed as good, single hub	60 per ct. to 70 per ct.
" " " " double "	20 per ct. to 30 per ct.
" " special castings, including Y's and T's	60 per ct.

5″ pipe extra heavy :

Percentage passed as good, single hub	25 per ct. to 35 per ct.
" " " " double "	No record.
" special castings, including Y's and T's	60 per ct.

It has been stated to me by dealers, that the tar coating does away with the necessity of any such test as the oil; while I am not prepared to acknowledge or deny the statement, it is well known that much poor pipe is tar-coated and sold in the market as good, and when coated it is almost impossible to detect any but *very* defective work.

The price customers are obliged to pay for soil pipe, either "heavy" or "extra heavy," is very high indeed, even taking off the discounts, and amounts (as I figure it) to $70 per long ton for 4″ pipe. The present rate for the best water pipe of the same calibre is about $38 (now $29) per long ton, and the additional charge for soil pipe should guarantee the very best iron in the market, though it appears to be rarely furnished.

It is asserted that all soil pipe is tested to a 50-pound water pressure. I beg leave to question the absolute truth of this, unless it be acknowledged that pipe is sold indiscriminately, whether it bears the test or not, for more than once I have found a single length of soil pipe (5 feet) that could not bear the pressure of a column of water of its own height without leaking.

Having obtained a satisfactory lot of soil pipe and fittings, the next trouble comes with the lead calking. Unfortunately it is frequently found that very shallow joints are made instead of deep ones, and hard lead used instead of soft. My rule is, soft lead. two runnings and two calkings. By soft lead I mean pig lead, and by hard lead I mean old pipe and scrap lead that may have been melted a dozen times. Incidentally it may be remarked that it is quite difficult to calk a tight joint on the heavy pipe ; the process will crack the hub.

The fixtures used in a house are of minor importance—there are dozens of good patterns of every class. If they are carefully put in, and provided with suitable traps placed just as close to the fixture as possible, the result will usually be satisfactory.

Very few instances occur where traps are placed as close to the fixtures they serve as they might be, and yet a very short length of untrapped pipe, when fouled, will sometimes smell dreadfully. A set bowl with trap two feet away may become in time a great nuisance if not properly used. A case in point where the fixture was used both as a bowl and a urinal was in a few months exceedingly offensive—a fact largely (though not wholly) due to its double service.

I have never met two sanitarians who agreed upon the same water-closets, bowls, faucets, traps, etc.

Of course, the soil pipe will be carried, of full size, through the roof, and sufficiently high to clear all windows.

Avoid multiplicity of fixtures or pipes; cut off all fixtures not used at least twice a week, lest their traps dry out; have all plumbing as simple as possible, and try and get it all located so that outside air can be got directly into all closets and bath rooms. As far as possible, set your fixtures in glass, rather than tiles or wood. Carry the lower end of the main drain at least five feet beyond the cellar walls of the building, of cast iron.

Let us now look at the outside work. The main drain (carrying everything except the kitchen and pantry sinks) goes through a ventilated running trap. An indirect fresh-air inlet is provided on the house side of the trap (example), to prevent annoyance from puffing or pumping, or, better still, a pipe corresponding to the soil pipe is carried up on the outside of the house.

The running trap ventilator should be of the same diameter as the main drain (4 inch), and serve as a main drain vent also. Carry this pipe on the outside of the house as high as the top of the chimney.

A grease-trap should be provided for the kitchen and pantry sinks. Formerly my custom was to put in brick receptacles; it is now to put in Portland cement traps (Henderson pattern), though perhaps I may succeed in devising a cast-iron one that will answer better. The brick ones were occasionally heaved by the frost, and cracked; the Portland cement ones answer better, and when thoroughly painted with red lead do not soak an appreciable quantity of sewage to be offensive, but are too high-priced ($28 each). I have made one or two patterns for cast-iron ones, but none as yet that I feel satisfied with.

Beyond the running trap an Akron pipe should convey the sewage to a tank or cesspool.

Our supposable case is the second most difficult to take care of. The worst would be ledge. We have to contend with, however, hard, wet, impervious clay.

The best way undoubtedly is to underdrain the land and then to distribute the sewage on the principle of intermittent downward filtration. This is rather expensive, and a customer is rarely willing to pay the bills for the same. I should always advise it as the best; but where not allowed to do so, I have had fair success with shallow French drains connecting with the tank or cesspool.

Siphon tanks, such as are advised by many sanitarians, that were used first in this country, I believe, by Mr. Waring, I have not been very successful with. Obstructions get into the siphon and stop it up, or it gets choked with grease. I prefer a tight tank, provided with a tell-tale, and that is to be opened either by a valve operated by hand or that is arranged with a standing overflow like a bath tub, and that can be raised and secured by a hook.

SEWERAGE AND HOUSE DRAINAGE IN ST. LOUIS.

By Robert Moore, Member Engineers' Club of St. Louis.
[Read December 3, 1884.]

The sewerage system of St. Louis dates from the year 1849, which was also the year of "the great fire" and of the severest visitation of cholera in the history of the city. Prior to this time no sewers, in the modern sense, had ever been built in the city. A few stone or brick culverts had been built by private parties across the levee to drain property immediately adjacent thereto ; but they were not intended for the reception of house drainage, and as a rule this use of them was expressly forbidden by a special proviso in the several ordinances which authorized their construction.* But now the building of sewers as a sanitary measure for the removal of household and manufacturing wastes, as well as surface water, was undertaken, and a system devised which was intended to embrace the whole city.

In taking this step, St. Louis was preceded by very few cities either in this country or in Europe. It is true that before this time sewers for the carriage of surface water were in the older cities not uncommon. But in none of them, not even in London, was the building of sewers, prior to 1849, more than begun in any serious and systematic way as a sanitary measure. And it was common in England, before this time, as it had been in St. Louis, to forbid the using of the sewers for the drainage of houses or for the removal of anything but surface and storm waters. Nor was this step in St. Louis a sudden one, forced upon the people by the terrors of pestilence. The statute which empowered the city to proceed in the construction of sewers was passed during the winter preceding the epidemic of cholera, its approval being dated March 12, 1849, and was the final result of a discussion which had been going on, in the City Council and in the newspapers, for not less than eight years. This early discussion of the subject grew primarily out of one of the topographical features in which, as compared with other cities, St. Louis is peculiar—to wit : the presence of numerous "sink-holes," or basins, whose only drainage is through fissures in the underlying rock. These abounded in nearly every part of the city, and it was a favorite opinion with many that these natural underground outlets mights be permanently relied upon to carry off not only surface water, but sewage matter as well.

One of these basins, whose centre was not far from the intersection of

* See Ord. 626, June 19th, 1840. Ord. 679, Nov. 28th, 1840. Ord. 848, Nov. 17th, 1841. Ord. 965, May 4th, 1842. Ord. 993, June 6th, 1842. Ord. 1204, July 24th, 1843.

Ninth and Biddle streets, in what was then known as "the northwestern part of the city," was the source of much solicitude, as the area drained included many blocks, and the results of any stoppage of the outlets were sure to be very serious. During 1841 and 1842 several reports were made to the Council by the city engineer, setting forth the importance of preserving these outlets, and several ordinances were passed appropriating money for the purpose of protecting them and keeping them open. In May, 1843, the city engineer (Mr. Henry Kayser), in a further report to the Council, recommends the purchase by the city of the land (belonging then to Jonas Moore), upon which one of the largest of these sink-holes was located, there being, as he says, "the strongest probability that it will answer as a common sewer." The Mayor, John M. Wimer, in a message to the Council of the same date, also calls attention to this subject, but recommends, in opposition to the city engineer, that steps be taken toward the construction of a sewer as the only permanent and sufficient means of warding off the danger of overflow which is now constantly impending. Nothing being done, the subject was again brought up in May of the succeeding year, 1844, by the newly-elected mayor, Bernard Pratte, who in his first message joins in the recommendation made last year by the city engineer to purchase the sink-holes, there being, he urges, "good reason to believe from experience had thus far that they can be used as drains or natural sewers, and serve as substitutes for artificial ones." The Council referred the matter to a special committee, who, after careful examination on the ground, reported adversely to the recommendations of the Mayor and city engineer and urged the building of a sewer. Two months later an ordinance* was passed directing the construction of a sewer from the intersection of Seventh and Wash streets along Seventh street to Carr street, and thence under Carr street to the river, and authorizing an issue of $20,000 7 per cent. bonds to pay the cost thereof. Nothing, however, was done under this ordinance for the reason that the action proposed was beyond the powers then conferred upon the city by its charter, nor was the requisite power granted until five years later (March, 1849), as already related. Meantime the condition of things grew steadily worse. The outlets of the sink holes near Biddle and Ninth streets, which had been the subject of so much discussion, became stopped up, as nearly always happens in like cases, and a pond of stagnant water resulted, which was christened "Kayser's Lake," after the name of the city engineer who had urged the preservation and use of these outlets as permanent sewers. The need of sewers for purposes of house drainage, and particularly for the drainage of wet cellars in all parts of the city, had also become very evident, and public sentiment was ripe for the comprehensive system of sewerage, which, as before stated, was finally begun in 1849.

The outlines of this system in its present form, which, however, is not essentially different from its original form, are as follows :

All sewers are distributed into three classes, public sewers, district sewers, and private sewers. Public sewers are such as, in the words of the

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* Ordinance 1398, July 18th, 1844.

city charter, are "constructed along the principal courses of drainage." This class embraces all the main or trunk sewers into which the laterals are discharged. As a rule they are located in the valleys formerly occupied by streams; but in other cases they go through the ridges at considerable depth to drain sink-hole basins which formerly had no surface drainage. The first sewer constructed, begun in the summer of 1849, and intended for the drainage of Kayser's Lake, was of this latter kind. It is known as the Biddle street sewer, and where it passes through the ridge, at Broadway and Biddle streets, was constructed as a tunnel at a depth of about forty feet. It is a circular brick sewer, twelve feet in diameter, and was in its day counted as a great undertaking. The largest public sewer is of the former kind and follows the valley of Mill Creek, a stream which took its name from an old mill that once stood on it not far from Seventh and Poplar streets. West of the mill there stretched for nearly a mile and a half a long lake, known as "Chouteau's Pond," the site of which is now occupied by railroad depots and tracks. The sewer, which takes the water of the old stream, has a span of twenty feet and a clear height of fifteen feet, and is mainly built of stone. It drains an area of 6,400 acres, or ten square miles, and up to April, 1884, has cost $1,204,000. All public sewers are paid for by the city at large out of the general revenue.

The second class, or district sewers, embraces such as drain limited areas or districts, the boundaries of which are, as occasion requires, fixed by ordinance. They are, in fact, the branch, or lateral, sewers, in contradistinction to the mains, which are included in the former class. Sewers of this class are built by the city, but are paid for by the owners of the property within the district, the cost of the sewerage of the whole district being assessed upon the several lots of ground therein in the same proportion that the area of the lot bears to the area of the whole district after excluding all public streets and highways. The bills of assessment, which are by law made liens upon the property, are given to the contractor upon the completion of his work, and are collected by him without any recourse upon the city. Prior to 1859 the city paid the contractor in cash from the proceeds of bonds issued for each district, and collected the money from the property owners by a special tax running through a series of years until the bonds were extinguished. But this method was found not to work well, and was abandoned for the one now in use, which is on the whole satisfactory. The initiative in the construction of district sewers may be taken either by the property holders, upon petition, or by the city authorities, who may by ordinance direct the building of sewers in any district, whenever, in their judgment the public interest may so require. After district sewers are built they are maintained and repaired at the public cost, and are subject to the same regulation in all respects as public sewers.

The third class, that of private sewers, embraces all that are intended for the drainage of single houses or lots. These are built and paid for by the owners of the property drained, but are nevertheless by city ordinance made subject to certain general regulations, of which the following are the chief. No private sewer can be connected with any public or district sewer except in pursuance of a special permit therefor issued

by the Sewer Commissioner, who has general charge of the sewerage of the city. If the private sewer is to be used for the drainage of an inhabited house, the Sewer Commissioner is required before granting the permit to satisfy himself from an examination of the plan, a copy of which must be left with him, that provision is made, first, for preventing the passage of air into the house from the main sewer or from any other house drain, and second, for the ventilation of the drain within the house by a constant circulation of fresh air. The first of these ends is accomplished by means of the ordinary disconnecting trap, which must resist the passage of air by an obstacle equal to at least one inch in depth of water. The second is attained by requiring that there shall be an air inlet between the trap and the house, and that the main soil pipe shall be continued above the house and left open. The size of the drain and the materials used must also be approved by the Sewer Commissioner, and the work of making the junction with the main sewer must be done in the presence, and to the satisfaction, of an inspector detailed from the Department for that purpose. But beyond these general provisions all the details of the work within the house are left to the discretion of the owner. For private drains of any kind exceeding one hundred feet in length, the Sewer Commissioner can grant the permit only when the plan and profile of the proposed work have been approved by the Board of Public Improvements, and upon the deposit with the City Treasurer of money sufficient to pay the wages of an inspector appointed by the Sewer Commissioner to see that the work is properly done. These regulations concerning private sewers are of compartively recent date, the greater part of them having been drawn up by the writer, while acting as the first Sewer Commissioner under the present city charter, and passed by the Municipal Assembly in 1877 and 1878. Before that time it was the rule here, as elsewhere, to leave the private householder free to construct his house drains in any manner he saw fit, provided only that he did not injure the main sewer by his manner of making the junction. As a consequence, these drains were very commonly constructed in gross violation of all the requirements of sanitary science. In particular, no attention whatever was paid to the ventilation of house drains. The soil pipe was terminated at the highest fixture, and there was no provision for admitting any air except that of the main sewer. In this, however, St. Louis was not behind other American cities, and the ordinance passed here, providing for the ventilation of all house-drains built thereafter and their disconnection from the air of the sewer was, I believe, the first one of the kind enacted in this country, though such ordinances have since then become very common.

Each of these three classes of sewers is designed and used to carry off the rainfall as well as the waste water from houses, and the whole therefore is an example of what is known as the "combined system." At first, indeed, the chief object of their construction was to get rid of storm water, which by collecting in ponds and cellars had become a nuisance. With sewers already built for this purpose the construction of another system for the carriage of house drainage only, as would be required to meet the views of the more strenuous advocates of the "separate system," has been found wholly unnecessary, and has not even so much as

been thought of. Nor, so far as the writer knows, has this two-fold use of the sewers been productive of any evil results whatever.

The amount of rainfall which the public and district sewers are designed to carry is one inch in depth per hour from the whole area drained, experience having shown that the sizes given by this condition are admirably suited to the local circumstances. House drains are designed to carry off a still larger rainfall for the reason that the water which they receive gets into them much quicker than in the case of sewers draining larger areas. The usual rule is to make them large enough to carry off two inches per hour from the whole surface of the lot drained. The size of pipe called for to satisfy this requirement is very seldom larger than six inches, though prior to the adoption of the present regulations it was not uncommon to lay a twelve or even fifteen inch pipe for the drainage of a single house.

The grades of the sewers of all classes are, as a rule, quite steep. The minimum is one foot in one thousand, or one-tenth of one per cent., which is the grade of part of the Mill Creek sewer. The grades of other sewers range from this up to eight or ten per cent., the latter figures being not uncommon for house drains. The average in the district or lateral sewers is about one per cent., which is sufficient to secure a cleansing flow, and there is, I believe, no point in the city from which the sewerage is not carried to its final outlet within an hour after its entry.

This final outlet is in all cases the Mississippi River, whose rapid current and enormous volume are sufficient to carry off and harmlessly absorb all that can be brought to it. In this great receiver St Louis is particularly fortunate, as it forever settles the question of sewerage disposal, which in many other cities is one of very great and ever-increasing difficulty. It makes possible and fully justifies here a system of drainage which in other places and under other conditions might be impracticable and unwise.

In pursuance of the general plan thus outlined, work has gone forward with varying speed until up to April, 1884, there were built and in use $48\frac{1}{2}$ miles of public sewers, $174\frac{9}{10}$ miles of district sewers and about $58\frac{4}{10}$ miles of private sewers, including house drains, making a total of all classes of $281\frac{8}{10}$ miles. The area drained by district sewers is 4696 acres or $7\frac{1}{3}$ square miles. This embraces a large portion of the closely built parts of the city, including nearly all to which water pipe has been extended.

The cost of the system, exclusive of private sewers, whose cost is unknown, is as follows :

Public sewers	$2,942,827,	being $60,816	per mile.
District "	2,932,588	" 16,758	"
Total	$5,875,415	" $26,300	"

The results obtained by this large expenditure have been highly satisfactory. Before the construction of sewers much trouble was experienced throughout the city from standing water in cellars, even in the higher parts where such a thing would hardly be expected. Cellars of this sort frequently and very naturally became receptacles for garbage, and even under the most favorable circumstances were offensive and dangerous. So great was this difficulty of keeping cellars free from water that it was

not uncommon for persons who had put them under their houses to fill them up again.*

As a natural result of this state of things, the rate of mortality was very high. In the fourteen years from 1841 to 1854, inclusive, the average death rate is given by Dr. George Engelmann, after a very careful study of the records, as $43\frac{6}{10}$ per 1,000. Of these years no less than five (viz., 1849, 1850, 1851, 1852 and 1854) were marked by the presence of cholera, which found here such a congenial home that it threatened to become a permanent resident. But even after eliminating the deaths from cholera, Dr. Engelmann finds the normal death rate of that period to be no less than 34 per 1,000.†

To-day a permanently wet cellar in St. Louis is a rare phenomenon. Within the area covered by sewers the soil has been rendered thoroughly dry and clean. And, taking the statistics of the last eight years from 1876 to 1883 inclusive, we find the average death rate to be now but 19 8-10 per 1000, or less than sixty per cent of what it was before the construction of sewers, and as low as any large city in the world. Of course this result is not due to any single cause. An improved water supply; better housing, an increased knowledge of the laws of health, and more vigorous measures to abate nuisances and stamp out contagious diseases have all contributed to lengthen life and lower the death rate. But with all this, nothing is more certain than that these agencies would have been comparatively futile without the purification of dwellings and the drying of the soil which the construction of sewers alone has made possible.

ON THE FAILURE OF THE COLUMNS OF ONE OF THE GAS-HOLDERS OF THE ST. LOUIS GAS CO.

By J. B. Johnson, Member of the Engineers' Club of St. Louis.

[Read December 17, 1884.]

The recent failure of one of the large gas-holders of this city has awakened considerable interest in this locality, and much speculation has been indulged in as to its cause. It is thought to be of sufficient interest to bring before the Club.

There were twelve cast iron, hollow, cylindrical columns, each 75 feet

* The testimony on this subject in the newspapers of 1849 is very ample. Thus, on January 27th, 1849, the St. Louis *Republican*, conducted by Col. A. B. Chambers, states editorially that "There are few blocks in the city where there are not cellars containing more or less water. A large number are full or nearly so—particularly east of Fourth street." In its issue for January 3d, the same paper has the following: "There are cellars in Pine, Olive, and Locust streets that have not been free from water for years past, and even now their condition is most offensive." On the same date, Doctors Pope, McMartin and McCabe, in a memorial to the Board of Health, say: "Numerous cellars and basements, flooded as they are after every rain, are believed to be one of the most prominent sources of disease in St. Louis."

On February 28th, the *Republican* in an editorial has the following: "At present the street gutters are the only sewers. These in warm weather become exceedingly offensive. In addition, in many parts of the city, cellars cannot be kept dry. Day before yesterday we saw the owner of a block of buildings filling up finished basements because of the impossibility of draining them."

† See paper by Dr. George Engelmann in "Report on the Diseases of Missouri and Iowa. By Thomas Reyburn." Philadelphia, 1855.

high, supporting a holder 140 feet in diameter. The whole was erected in 1857, and failed by the southern columns breaking outward on the night of December 11, 1884. Snow had fallen during the day and evening, and this had a tendency to drift over on the south side.

The columns were cast in solid sections about nine feet in length, with flanges turned inward, being bolted together on the inside through the flanges. They were three feet in diameter at bottom and two feet in diameter at top. The metal of the shell would average about one-half inch in thickness. The columns on the north side broke off near the top, while those on the south side broke in the middle and at bottom.

The failure was caused by the upper, or inner, section of the holder getting pinched or caught, while settling down inside the lower and outer section. It was caught in this manner on the north side, when the top was some 22 feet above ground. The two sections are each 35 feet high, so the upper section had already moved down through the lower one a distance of some 13 feet. *There were no guide, or friction, rollers on the inside to prevent this pinching action.* Had there been, such an accident could never have happened. This same thing has occurred before, and the remedy has been to let in more gas and so lift the tank up and force it from its inclined position. The first warning, in this case, was the sound caused by the cracking of one of the south columns. The watchman then found this column broken at bottom and in the middle, being a foot or two out of line at centre, with the south side of the tank some *ten feet lower than the north side*, as nearly as he could estimate. Soon another column broke, but they did not fall for about half an hour after the first break was discovered. In the meantime the gas had been shut off from this holder.

The final catastrophe, as described by the Superintendent, who was an eye-witness, was about as follows: The two broken columns, on the south side, fell away, the middle falling outward and tops inward. The top trussing, connecting the columns, fell upon the top of the holder and broke two holes a foot or two in diameter. The gas at once escaped from there and took fire, probably from a friction spark. The tank, being relieved of the inward pressure, settled away towards the south, until it pulled the remainder of the columns after it, when, the tops of the northern columns, with the trussing here, falling upon the top of the holder, it gave way generally, and the gas, escaping in solid mass, was burned as though it came from a burner. *There was no explosion*, unless the first ignition might be called such. The Superintendent stated that, when the first escaping gas ignited, he was forcibly thrown forward upon his knees by the in-rushing air, he being about 100 feet away from the northeast portion of the tank. There was a stiff breeze blowing from the north, and had been all day. The snow had a tendency to drift somewhat over on the south side of the holder, as the top was spherical. The breeze and unsymmetrical snow-load both tended to cause the lower edge of the north side to hug the inner face of the outer shell in settling away. There being no rollers to keep it off, it got caught on rivet heads, or in some other way, and the more the rest of the tank settled, the tighter this was held, and so failure became inevitable.

It has been suggested that the overweight on the inside of one of the

northern columns may have got caught under the projecting flange of a column joint, as the vibration of the columns from wind often causes the weights to pound the sides of the columns, and there is nothing to hinder their catching on the flanges. This cannot explain the accident, however, since the lower section of the holder, to which the overweight chains are attached, was quite down and the upper section had already descended thirteen feet. The overweights were, therefore, stationary at the tops of the columns.

Unsymmetrical Load from Overweights.

The overweights hung inside the columns, the chain passing over a pulley at top and down to the lower section of the shell, where it was fastened at a distance of twenty inches from the outside of column at bottom, or thirty-eight inches from the axis of column. The overweight was a cast-iron shell, ten feet long, 15 inches in diameter, web 1¼ inches thick, and weighted by being filled in with iron scraps, to within 18 inches of the top. The weight of this was about 3,800 pounds. It was balanced by a corresponding pull on the lower shell, making a total load on the pulley of 7,600 pounds. The weight of the chain and suspending rods would make the total load hung from the axis of the pulley about 8,000 pounds. *The line of action of this weight on the pulley was twenty-one inches from the column axis.* The weight of the column itself was about 12,000 pounds. The moment of the load on the pulley, tending to bend the columns and causing unequal stresses in inner and outer sides ("inner" meaning toward the holder and "outer" away from it), was, therefore, 8,000 × 21 = 168,000 in. pds. We can now find the actual stresses on inner and outer sides of the column at any section.

If p_0 = mean intensity of stress at any section in the column if total load were symmetrically distributed.

p_1 = maximum intensity on inner side.

p_2 = corresponding intensity on outer side.

x_0 = distance from column axis to line of action of the resultant for the total load.

x_1 = distance from column axis to extreme fibre = radius.

S = area of the flange in cross-section.

I = moment of inertia of this area about an axis through the centre.

Then we have

$$p_1 = p_0 \left(1 + \frac{x_0\, x_1\, S}{I}\right) \text{ and}$$

$$p_2 = p_0 \left(1 - \frac{x_0\, x_1\, S}{I}\right)$$

But for hollow cylinders, having d and d_1 for their outer and inner diameters, respectively, we have :

$$\frac{x_1\, S}{I} = \frac{8\, d}{d^2 + d^2}.$$

From the data above given, we may write :

For Top Section.

$W = 0$. $W^1 = 8{,}000$ pounds.

$p_0 = 216$ pounds per sq. inch,

$x_0 = 21$ inches.

$$\frac{x_1 S}{I} = .175$$

whence $p_1 = 1{,}000$ pounds compression on inner sides,
and $p_2 = 570$ " tension " outer "

For Middle Section.

$W = 6{,}000$ pounds. $W^1 = 8{,}000$ pounds.
$p_0 = 300$ pounds per sq. inch.
$x_0 = 12$ inches.

$$\frac{x_1 S}{I} = .138$$

whence $p_1 = 800$ pounds compression on inner side,
and $p_2 = 200$ " tension " outer "

For Bottom Section.

$W = 12{,}000$ pounds. $W^1 = 8{,}000$ pounds.
$p_0 = 360$ pounds.
$x_0 = 8.4$ inches.

$$\frac{x_1 S}{I} = .114 ;$$

whence $p_1 = 690$ pounds compression on inner side,
and $p_2 = 30$ " " " outer "

We see, therefore, that there is tension on the outer sides of the columns due to the unsymmetrical placing of the balancing loads. This tension is greatest at the top, and becomes zero near the bottom, at the top being as great as 570 pounds per square inch. If the overweight were hung on the outside of the column instead of in the open centre, then this load could be placed symmetrically over the centre of the column and the stresses would then be uniform over the cross section, wherever this section be taken. The column then could not fail for the steady load until it so far decayed as to crush away under a maximum stress, for this case of 360 pounds per square inch.

Wind Pressure.

Although there was but a slight wind when the structure fell, there are many old cracks about the columns which may have been caused at some time by wind. It is, therefore, well enough to examine the strains that would be caused by, say, a 20-lb. wind or a wind of 60 miles an hour.

The area of a diametral section, for the holder standing 60 feet above ground, is $60 \times 140 = 8{,}400$ square feet. If the pressure on a cylindrical surface is half what it is on a flat surface, we have, for total wind pressure,

$$10 \times 8{,}400 = 84{,}000 \text{ pounds.}$$

There are two sets of bearing or guide wheels which would transfer this pressure to the columns, one at the top of the upper shell and one at top of lower shell. If these be 35 feet apart, the resultant thrust may be taken at about 40 feet above the base of the column. Although this would be carried directly by six or seven columns, yet it would be distributed about equally among the twelve by the trussing at the top which connects all the columns together.

The average pull on the *top* of each column would therefore be

$$\frac{84{,}000 \times 40}{12 \times 75} = 3{,}700 \text{ pounds.}$$

This gives a bending movement at the bottom of each column of 3,780,000 inch pounds.

The moment of resistance of a hollow column, to bending, is :

$M_0 = n f d^3$ where f is the ultimate strength, d the diameter, and n a numerical factor, which in this case is $\frac{1}{10.2}\left(1 - \frac{d'^4}{d^4}\right)$ where d' is the internal and d the external diameter. At bottom of column, $d = 36$ inches and $d' = 35$ inches. Therefore, $n = .01$ and $M_0 = .01 f d^3 = 466 f$.

$$\therefore \quad f = \frac{3{,}780{,}000}{466} = 8{,}000 \text{ lbs. per sq. inch.}$$

If we consider the tension side only, which is the *outside* of column to windward, and *inside* of column to leeward, then we must combine this tension due to wind moment with the stress in those fibres due to steady load. This we have found to be 30 pounds compression on the outside and 690 pounds compression on the inner side. Therefore, the maximum tension at bottom of column comes on the windward column on the outside, and is about 8,000 pounds per square inch. This is about one-half the average ultimate strength of cast-iron in tension. If the iron was poor, or if there were flaws or annealing cracks, this might be beyond the ultimate strength of the column. It will be noted this computation is based on a 60-mile wind, which is not a very uncommon record on the St. Louis signal service gauge.

Again, the column is much weaker in tension on account of the style of joint used. This form is good for compression alone, but is not to be recommended for tension. It is, therefore, highly probable that several of the columns have been cracked at various times by the wind moment brought upon them.

The Contingencies of Handling.

In determining the proper thickness of web to be given to a cast-iron tube or column, it is not enough to satisfy the conditions of stress after the pipe is in place ; but, in case of small pressures with large diameters, with pipes, and small loads with large diameters, in columns, we must provide against the ordinary contingencies in the way of jars and shocks in the handling and erection or laying. In the present case, this part of the investigation is very significant. Thus, the bottom sections are 36 inches in diameter and only an average of ½ inch in thickness, this reducing to about one-fourth inch in places. It appears that there are now found many longitudinal cracks in these shells which appear to be old, and in one case I observed where such a crack had been fastened together by a wrought-iron plate riveted on the inside. This must have been done before the section was put up, and the crack was probably caused by some shock received in the handling. It is quite evident that cast-iron shells 3 feet in diameter and ½ inch in thickness are likely to be injured by ordinary handling.

Snow Load on Gas-Holder.

It has been asserted that the weight of the snow on the top of the tank had some effect on the failure of the columns. There are two ways in which this effect is supposed to appear.

First. By increasing the load on the columns. This cannot be ; for the

load on the columns, aside from its own weight, can only be twice that of the overweight, which is not increased for snow load. The effect of the snow is only to press the holder a little farther into the water, thus displacing an additional amount of water equal to the weight of the snow. The pressure of the gas is increased then by this much.

Second. By flattening out the spherical top of the holder, spreading the outer circumference at top thus increasing the diameter and so pressing the guide-wheels out against the columns with sufficient force to bend them outward until they fail. This theory is based on an erroneous conception of the applied forces. The downward load due to the snow is not taken up and resisted at the circumference, thus causing the top to sag, or flatten itself somewhat, but this load is *entirely* resisted by a corresponding increase in the gas pressure, so that, *if the snow load is uniformly distributed,* the load on any one square foot of top is resisted by the increase of upward pressure on that same square foot of surface, and the only effect is to compress the metal by so much. *There is no tendency for the crown, or top, of the tank to change its shape.*

If, however, the snow load *is not uniformly distributed,* but is drifted badly to one side of the top of the tank, then there is a uniform increase of gas pressure due to the entire snow load, which reaction is uniformly distributed over the entire inner surface. The downward forces, acting only on one side, gives rise to an overturning moment equal to the weight of the snow into the distance of its centre of gravity from the vertical axis of the tank. This moment is resisted by a couple, consisting of an outward thrust against the columns at top on the snow side and another equal outward thrust against the base walls on the opposite side at bottom. The outward pressure against the columns would act exactly like a wind pressure, which has already been discussed, and the amount of it could be determined when the weight of the snow, the position of its centre of gravity and the height of the top guide roller above base of column, are known.

The following conclusions may be drawn :

1°. That the failure is traceable directly to a lack of guide, or friction, rollers between the two sections of the holder.

2°. That the sections of the columns were too thin to resist the ordinary shocks from handling.

3°. That the columns were more or less cracked when they were put up.

4°. That the columns had not sufficient strength at the base to resist the action of the wind on the gasometer.

5°. That the overweights should have been suspended outside the columns so as to bring this load symmetrically over the axis of the column.

6°. The columns should have been protected from rusting on the inside.

7°. The sections should have been united by a wrought-iron band on inside, riveted to the two adjoining sections.

8°. That if the over-load is symmetrically placed, the only stress in the column that requires investigation is that due to wind pressure.

9°. That any distributed load on the top of the gasometer, as snow, plays no part in the problem of the columns.

10°. That an unsymmetrically distributed snow-load may have had something to do with this failure.

11°. That the columns should be made of wrought, instead of cast, iron.

12°. That friction rollers should never be omitted between the sections of a holder.

RAPID CONSTRUCTION OF THE CANADIAN PACIFIC RAILWAY.

By E. T. Abbott, Member of the Engineers' Club of Minnesota.

[Read December 12, 1884.]

During the winter of 1881 and 1882 the contract was let to Messrs. Langdon, Sheppard & Co., of Minneapolis, to construct during the working season of the latter year, or prior to January 1, 1883, 500 miles of railroad on the western extension of the above company; the contract being for the grading, bridging, track-laying and surfacing, also including the laying of the necessary depot sidings and their grading. The idea that any such amount of road could be built in that country in that time was looked upon by the writer hereof, as well as by railroad men generally, as a huge joke, perpetrated to gull the Canadians. At the time the contract was let the Canadian Pacific Railway was in operation to Brandon, the crossing of the Assiniboine River, 132 miles west of Winnipeg. The track was laid, however, to a point about 50 miles west of this, and the grading done generally in an unfinished state for 30 miles further. This was the condition of things when the contract was entered into to build 500 miles—the east end of the 500-mile contract being at Station 4,660 (Station 0 being at Brandon) and extending west to a few miles beyond the Saskatchewan River.

The Spring of 1882 opened in the most unpromising manner for railroad operations, being the wettest ever known in that country. Traffic over the St. Paul, Minneapolis & Manitoba Railroad, between St. Paul and Winnipeg, was entirely suspended from April 15th to the 28th, owing to the floods on the Red River at St. Vincent and Emerson, a serious blow to an early start, as on this single track depended the transportation of all supplies, men, timber and contractors' plant, together with all track materials (except ties), all of these things having to come from, or through St. Paul and Minneapolis, The writer hereof was appointed a Divison Engineer, and reported at Winnipeg the 15th of April, getting through on the last train before the St. Vincent flood. No sooner was the line open from St. Paul to Winnipeg than the cotillion opened between Winnipeg and Brandon, with a succession of washouts that defied and defeated all efforts to get trains over, so it was not until the fifth day of May that I left Winnipeg to take charge of the second division of 30 miles.

By extremely "dizzy" speed I was landed at the end of the track, 180 miles from Winnipeg, on the evening of the 9th (4 days). My outfit consisted of three assistant engineers, and the necessary paraphernalia for three complete camps, 30 days' provisions (which turned out to be about 20), 11 carts and ponies, the latter being extremely poor after a winter's

diet on buffalo grass and no grain. On the 18th day of May I had my division organized and camps in running order. The country was literally under water, dry ground being the exception, and I look upon the feat of getting across the country at all as the engineering triumph of my life.

On May 20th a genuine blizzard set in, lasting 24 hours, snowed five inches, and froze the sloughs over with half an inch of ice, a decidedly interesting event to the writer, as he was 18 miles from the nearest wood, therefore laid in his blankets and ate hard tack. I stabled my ponies in the cook tent, and after they had literally eaten off the sod inside the tent, I divided my floor with them.

On the 28th day of May I saw the first contractor, who broke ground at station 7,150. On the 1st of June I was relieved from this division and ordered to take the next, 50 miles west. On the 13th day of June ground was broken on this division at station 8,070, or only about 62 miles west of the east end of the 500-mile contract. It looked at this time as though they might build 150 miles, but not more. But from this time on very rapid progress was made. On July 17th the track reached station 7,000, making however up to this time but about 50 miles of track-laying, including that laid on the old grade ; but large forces were put on to surfacing and the track already laid was put in excellent condition for getting material to the front. The weather from this until the freeze-up was all that could be desired. Work ceased about the 1st of January, 1883, for the season, and the final estimate for the work was as follows : 6,103,986 cubic yards earth excavation, 2,395,750 feet B. M. timber in bridges and the culverts, 85.708 lineal feet piling, 435 miles of track-laying. This work was all done in 182 working days, including stormyones, when little, if anything, could be done, making a daily average of 33.548 yards excavation, 13,150 feet B. M. timber, 471 feet piling, $2\frac{38}{100}$ miles track-laying. We never had an accurate force report made of the whole line, but roughly there were employed 5,000 men and 1,700 teams.

The admirable organization of the contractors was something wonderful. The grading work was practically all done by sub-contractors, Messrs. Langdon, Sheppard & Co. confining themselves to putting in the supplies and doing the bridge work, surfacing and track-laying. The grading forces were scattered along about 150 miles ahead of the track and supply stores, established about 50 miles apart, and in no case were sub-contractors expected to haul supplies over 100 miles. If I remember rightly there were four trains of about forty wagons each, hauling supplies from the end of track to the stores.

As can be readily seen, the vital point of the whole work and the problem to solve was food for men and horses. 1,700 bushels of oats every day and 15,000 pounds of provisions, Sundays and all, for an entire season, which at the beginning of the work had to come about 170 miles by rail, and then be taken from 50 to 150 miles by teams across a wilderness, is on the face of it considerable of an undertaking, to say nothing about hauling the pile-drivers, piles and bridge-timber there. To keep from delaying the track, sidings 1,500 feet long were graded, about 7 miles apart. A side-track crew, together with an engine, four flats and caboose, were always in readiness, and as soon as a siding was reached, in five hours

the switches would be in and the next day it would be surfaced and all in working order, when the operating department would fill it with track material and supplies. From the head of the siding to the end of the track the ground was in hands of track-layers, the track-laying engine never going back of the last siding for supplies or material, and my recollection is that there was but six hours' delay to the track from lack of material the whole season, at any rate up to sometime in November. The track-laying crew was equal to 4 miles per day, and in the month of August 92 miles of track was laid.

The ties were cut on the line of the road about 100 miles east of Winnipeg, so the shortest distance any ties were hauled was 270 miles; the actual daily burden of the single track from Winnipeg west was 24 cars steel, 24 cars ties, aside from the transportation of grain and provisions, bridge material and lumber for station houses. The station buildings were kept right up by the company itself and a depot built with rooms for the agent every 15 miles, or at every second siding. The importance of keeping the buildings up with the track was impressed on the mind of the superintendent of this branch, and, as a satire, he telegraphed asking permission to haul his stuff ahead of the track by teams, he being on the tracklayers' heels with his stations and tanks the whole season. The telegraph line was also built, and kept right up to the end of the track, three or four miles being the furthest they were at any time behind.

It might be supposed that work done so rapidly would not be well done, but it is the best built prairie road I know of on this continent. It is built almost entirely free from cuts, and the work is at least 20 per cent. heavier than would ordinarily be made across the same country in the States on account of snow. 2,640 ties were laid to the mile and the track ballasting kept well up with the laying; so well, in fact, and so well done, that as 100-mile sections were completed schedule trains were put on 20 miles an hour, and the operating department had nothing to do but make a time table; the road was *built* by the construction department before the operating department was asked to take it. The engineering was organized in divisions of 30 miles each, and as each was finished the parties moved ahead again to the front, the engineers usually finding men sitting on their shovels waiting for the work to be laid out for them. It was as much as the locating parties could do to keep out of the way of the construction. The road-bed was built 14 ft. wide in embankment and 20 in the very few cuts there were, there being no cuts of any moment except through the Coteaus and the Saskatchewan crossing, and these have since been widened out on account of snow, so that the road can be operated the year around and the bucking-snow account cut no figure in the operating expenses.

The country is a virgin desert. From Winnipeg to the Pacific Ocean there are a few places that might attain to the dignity of an *oasis*—at Brandon, Portage la Prairie, etc., but it is generally what I should call worthless, 100 miles to wood and 100 feet to water was the general experience west of the Moose jaw, and the months of June, July and August are the only three in the year that it is safe to bet you will not have sleighing. I burned wood and used stakes that were hauled by carts 85 miles, and none any nearer. It is a matter of some pride that both the engi-

neering and the construction were done by what our Canadian neighbors kindly termed "Yankee importations." However, there was one thing that in the building of this road was in marked contrast to any other Pacific road ever constructed, that is, that there was no lawlessness, no whisky, and not even a knock-down fight that I ever heard of the whole season, and even in the midst of 12,000 Indians, all armed with Winchester rifles and plenty of ammunition, not one of the locating or construction parties ever had a military escort nor were any depredations ever committed, except the running off of a few horses, which were usually recovered, and I think there were but two fatal accidents during the season, one man killed on the Grand Coulé Bridge, and another from being kicked by a horse.

The track was all laid from one end, and in no case were rails hauled ahead by teams. Two iron cars were used, the empty returning one being turned up beside the track to let the loaded one by.

The feat in rapid construction accomplished by this company will never be duplicated, done as it was by a reckless expenditure of money, the orders to the engineers being to "*get there*" regardless of expense and horse-flesh; if you killed a horse by hard driving, his harness would fit another, and there was no scrutiny bestowed on vouchers when the work was done, and I must pay the tribute to the company to say that everything that money would buy was sent to make the engineers comfortable. It was bad enough at best, and the Chief Engineer (J. C. James) rightly considered that any expense bestowed on the engineering part of the work was a good investment.

PROGRESS IN ASTRONOMICAL TELESCOPES.

By W. R. Warner, Member of the Civil Engineers' Club of Cleveland.
[Read January 13, 1885.]

The history of the astronomical telescope dates back but two and three-quarter centuries, previous to which time no practical advance had been made in the science of astronomy for more than a thousand years. The credit for the invention has been claimed by the friends of three parties, Lipperhey and Jansen, of Holland, and Galileo, of Italy. No one claims that Galileo first discovered the principle of the refraction of light; but that he first applied it to an instrument for observing the stars, there is no doubt.

In 1608, while in Venice, he learned that Jansen had, by a combination of pieces of curved glass, succeeded in making distant objects appear much nearer. He at once gave the subject his attention, and in a few months he had completed an instrument that magnified three times.

He then made other and larger ones, the largest of which magnified but thirty times, and was, of course, very imperfect; but with it he discovered the mountains in the moon, the satellites of Jupiter, the phases of Venus, and what seemed to him handles on the planet Saturn.

The Galilean telescope was very nearly the same as the modern opera-glass, being composed of one double convex lens and one double concave lens, placed as shown in Fig. 1, the light passing through both lenses

before reaching a focus. The large lens is called the object glass, or objective, and the small one the eye-piece.

A difficulty was soon encountered, which, for a century and a half, prevented large and powerful refracting telescopes from being made. It was found that a ray of light, when refracted by the lens, was separated into all the colors of the rainbow. These were called prismatic colors, and they surrounded every object observed through Galileo's telescope. This is shown by the passage of a beam of light through a triangular prism, Fig. 2, or more plainly in its application to the telescope in Fig. 3, where the line at a–b is the axis of the lens, and c–d a parallel ray of white light, which, on passing through the lens, is refracted and separated into the prismatic colors, the red ray meeting the axis at r, and the violet ray, being most refracted, meeting the axis at v. This, as will be evident, gives a confused image of the star. This difficulty is called chromatic aberration, and it prevents an exact image of the star or object observed being made anywhere on the optical axis of the lens. From the fact that the chromatic aberration is the same in glasses of long and short focus, while the image of the star or object observed is proportionately larger in the former, the astronomers of the 17th century made their telescopes very long—in some cases the focus being over two hundred feet.

As the magnifying power of a telescope is found by dividing the focal length of the object glass by that of the eye-piece, it will be evident that in these long telescopes a low-power eye-piece would give a high magnifying power and reduce the chromatic aberration to a minimum.

The "color line" so marked in optics, as well as politics, led the astronomers to study other means than lenses for getting a luminous image of distant bodies. It was discovered, we know not by whom, that parallel rays of light striking a parabolic mirror were reflected to a point at the focus, as in Fig. 4. Newton was the first to apply this principle practically to the astronomical telescope. He made the parabolic mirror of long focus and intercepted the rays by a 45° mirror just before they came to a focus, thus bringing the image of the object outside the tube, where it is examined by the eye-piece, as in Fig. 5. This is called the Newtonian reflector.

Herschel tilted the parabolic mirror, as in Fig. 6, thus bringing the focus to the edge of the tube, where the eye-piece is applied.

The most convenient method, and that adopted for the great Melbourne reflector, is the Cassegrainian system, where the cone of rays is intercepted before reaching a focus and reflected back through a hole in the center of the mirror, where it is examined by the eye-piece, as in Fig. 7. By this system the observer is near the ground when taking observations, while in the others some means must be provided for raising him in the air to the height of the top of the tube, which is a great inconvenience in large instruments.

Of the three systems of reflectors mentioned, the Newtonian is optically the best, while the Cassegranian is the most convenient to use.

As the rays of light are not separated into the prismatic colors by reflection, this system of telescopes was the most popular, and did the best work down to the middle of the 18th century, when Dolland, an

English optician, discovered that prisms of hard flint-glass dispersed the rays of light twice as much as those made of crown-glass (see Figs. 8 and 9), while the angle of refraction remained the same in each. This principle furnished the key to the modern refracting telescope, for by combining prisms of crown and flint glass, as in Fig. 10, having the angle of the flint half that of the crown, their dispersive powers are the same, and the ray of white light *a-b* will pass through both prisms and come out a white ray, *c-d*, the flint prism having counteracted the chromatic effect of the crown; while being but half the angle of the crown, it eliminated but half its refractive power.

This principle is applied to the telescope by making a double-convex lens, *a–b*, Fig. 11, of crown-glass, and just back of it place a plain convex lens of flint-glass, having half the curvature of the combined surfaces of the crown lens. The flint counteracts the chromatic effect of the crown lens, and the rays come to a focus at the same place. No exact rule can be given for the several curves for an object glass, for the refractive powers of glass made at different meltings varies greatly.

To determine the refractive powers of different pieces of glass, small prisms are made, and the indices of refraction found by trial. From these data the proper curves are computed.

We stated that the chromatic effect of the crown and flint glass was eliminated by combining them.

This is not exactly true, for if we make prisms of flint and crown glass having equal dispersive powers, we shall find that they do not disperse the rays uniformly, for in the crown the red band is broadest, while in the flint the blue is broadest. The result is that when combined they cannot wholly counteract each other, and in large instruments more or less color is always seen about a bright star.

This color is called the secondary spectrum, and being in the nature of the glass itself, no skill in working the glass can wholly correct it.

During the past fifty years great improvements have been made, both in refractors and reflectors. The largest reflector ever made is that constructed about 1840 by Lord Rosse, at Parsonstown, Ireland. This monster instrument, called "The Leviathan," is fifty-four feet long and has a mirror of six feet diameter. It is not mounted equatorially, but has a movement of 10° each side the meridian.

The large reflectors following it are those at Melbourne and Paris, each of four feet diameter. Many smaller reflectors are mounted in England, while in our country there are but few, for refractors seem to be much preferred. The mirrors or specula of the early reflectors were made of a composition of 32 parts tin to 15 parts of copper. In 1859, Foucault, a French physicist, invented the silvered-glass speculum, which greatly increased the value of the reflecting telescope. A disk of common glass is accurately ground on one side to the proper parabolic curve, on which a coating of silver about $\frac{1}{200000}$ of an inch in thickness is chemically deposited. This silver film can be polished or renewed at any time without affecting the figure of the speculum. The glass speculum also keeps its shape, and figures much better than one of speculum metal.

The four-foot reflector of the Paris Observatory has a silvered glass speculum, it being the largest ever made.

In 1840, Merz & Mahler, the renowned opticians of Munich, made a refracting telescope of 15 inches aperture for the Royal Observatory at Pulkowa, Russia.

This was the wonder of its time, and, indeed, not until 1862 was a larger one made, and then by our own countrymen, Messrs. Alvan Clark & Sons, who made one of 18½ inches aperture for the Dearborn Observatory of Chicago. This has been followed by a refractor of 25 inches aperture, made by Cook & Sons, of York, England. Our Washington telescope, of 26 inches aperture, made by the Clarks; also one of 26¼ aperture, for the McCormick Observatory, University of Virginia, and one of 23 inches aperture, for Halsted Observatory, Princeton, N. J., both by the Clarks; and one of 27 inches aperture, by Grubb, of Dublin, for the Imperial Observatory, at Vienna; and last and largest, the 30-inch refractor, made by the Clarks for the Royal Observatory at Pulkowa, Russia. This, however, will remain the largest but a short time, for one of the disks of glass is already cast for the 36-inch refractor for the Lick Observatory, now being built in California. The location of this Observatory is said to be the finest in the world. It is just inside the coast range of mountains on Mt. Hamilton, 4,400 feet above the sea and about 50 miles southwest of San Francisco. When finished, the Lick Observatory will be the most complete of any in the world. Besides the 36-inch refractor, there will be several smaller ones ; also meridian circles, transit instruments, and the great variety of instruments pertaining to astronomy. The question naturally arises, Is there any limit to the size and power of telescopes? And we can now answer yes, and say that probably the limit will be reached in the completion of the 36-inch Lick refractor, and has been reached in the Rosse reflector.

Of the two systems of telescopes, refractors and reflectors, each has its strong advocates, and each, doubtless, has advantages in certain kinds of work.

The lens of the refractor and the mirror of the reflector serve as light-gatherers, not as magnifiers. They give us a luminous image, and by the aid of the eye-piece, which serves as a microscope, we magnify that image. The perfection of the image and the amount of light with which to examine it, give us the limit of magnifying power we can use in the eye-piece.

In a reflector, the light-gathering power is represented by the proportion of light reflected, to the whole light that falls on its surface.

In a refractor, the light-gathering power is represented by the amount of light left after absorption by the glass and reflection from its several surfaces, in proportion to the whole light that falls on its surface.

This comparison will show that the light-gathering power of a unit of surface of a reflector is independent of its size, while in a refractor it diminishes as the size increases, on account of the extra absorption of light by the increased thickness of the glass. A limit, therefore, to the size of refractors will soon be reached, beyond which nothing would be gained by increasing the size. That limit is found to be between 34 and 36 inches.

The limit to the practical size of reflectors is met by the difficulty in keeping the mirror in proper figure and the unwieldy nature of the in-

strument. When we consider that the moderate size reflectors have surpassed the best work of the largest ones, we may feel sure that the practical limit has already been passed.

In comparing refractors with reflectors, we can say that the 26-inch refractor at Washington has shown the most difficult objects that have ever been seen.

The modern astronomical telescope, whether refracting or reflecting, is mounted equatorially, with the polar axis parallel to the axis of the earth, so that wherever the instrument is pointed, a movement about this axis will follow the apparent diurnal motion of the star. The declination axis being at right angles to the polar axis, enables the instrument to be pointed to any star in the heavens. Each axis carries a finely-graduated circle, from which is read the position of the star being observed.

The tubes of telescopes were formerly made of wood. The great Rosse 6-foot reflector has a wooden tube over 50 feet long, built up of staves and bound with iron. The Harvard College 15-inch refractor also has a tube of wood; but all large telescopes of recent date have tubes of sheet steel, which can be made very light and rigid.

The methods of reading the circles on large instruments have been so improved that, instead of climbing ladders with lantern in hand, the observer can sit at the eye end of his instruments and, by the aid of small telescopes fastened to the tube, and a series of prisms, can read the star's exact position, both in declination and right ascension.

Many systems of driving clocks have been devised to make the telescope to automatically follow the star. The conical pendulum seems to be the most satisfactory regulator, and by its aid the image of the star can be kept in the center of the field even under the highest powers. In the most exact kind of work, like spectroscopic observations, where the variation of $\frac{1}{10}$ of a second would vitiate the result, the driving clock is often connected electrically with the standard clock of the observatory. Methods have been devised by which all the movements of large instruments may be made by the observer or his assistant, by simply pushing a series of buttons, which make electrical connection with power from a hydraulic or gas engine.

We often hear exaggerated statements as to the magnifying powers of large telescopes. When we consider that all imperfections of the instrument, as well as all the disturbances of the atmosphere, are magnified as much as the star, we see that we shall soon arrive at a limit beyond which we cannot pass and retain a clear view of the object.

A newspaper item went the rounds a few years ago, stating that the largest telescopes showed the moon as if it were but 40 miles distant. As its real diameter is 240,000 miles, this would require a power of 6,000. Should the 26-inch refractor at Washington be provided with an eye-piece giving this power, the emergent pencil of light coming to the eye would be but $\frac{1}{230}$ of an inch in diameter, and the focal length of the eye-piece would be but $\frac{1}{16}$ of an inch.

Such a power would be manifestly absurd. A power of 100 to the inch of aperture is considered a maximum that can be used to advantage with the best glasses and under the most favorable circumstances, and it is seldom that more than 60 to the inch of aperture is used.

Professor Newcomb says: It is doubtful whether the moon has ever been seen with any telescope so well as it could be seen with the naked eye at a distance of 500 miles.

But a few years ago, only the largest universities could afford an astronomical observatory, and when, in 1843, Merz, of Munich, made a 15-inch refractor, a subscription was taken up by the citizens of Boston to purchase it and present it to Harvard College.

Until 1871 the largest telescope in the National Observatory at Washington was but 9½ in. aperture, but at the present time instruments of great power and excellence are in nearly every college of importance, and in many of the high schools of our country.

The interest, however, which has developed in the wonderful science of astronomy does not stop with the educational institutions, for many private observatories have been equipped, and their number is being multiplied every year.

The Chicago Astronomical Society was formed many years ago, and within the past month the "State Astronomical Society of Indiana" has been organized.

At the present rate of progress, the time is not far distant when every large city will have its Astronomical Society, as it now has its Civil Engineers' Club, its Attorneys' Club and its Literary Circles.

Cleveland is well prepared for such a society; for she has her Case School of Applied Science, her Adelbert College, her many men of learning and culture, with such a leader as our honored member, whose nightly vigils in his observatory on Case avenue have extended his fame even beyond the limits of our own country, and given scientific results of great value.

With these elements and such opportunities, let us look forward to the Cleveland Astronomical Society.

PROTECTION AGAINST FIRE.

By C. T. Aubin, Member of the Engineers' Club of St. Louis.

[Read January 7, 1885.]

In preparing this paper for our club, and not for the general public, I have omitted the tiresome description of an entire fire-proof building, the construction of which we are all familiar with. I have confined myself to a style of construction which, with the efforts of engineers and the co-operation of architects and house-builders, we may be able to obtain in the near future, as the additional cost is about two and one-half per cent., and which is, in my opinion, equal to any iron or brick arch. I have also for the same reason abstained from the description, protection and separation of steam boilers.

As to steam pipes, as engineers seem to differ, I have given you my own views upon the matter, which are the result of 18 years of my connection with the St. Louis underwriters.

The loss by fire in the United States and Canada for the year 1884 was \$125,000,000; in 1883 it was \$95,000,000, and we can depend upon \$160,000,000 for 1885.

To this irreparable loss we can, at the lowest figure, add the double of

Fig. 1

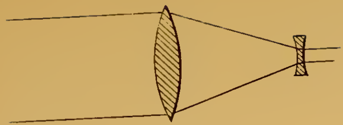


Fig. 2

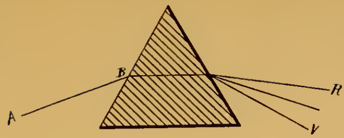


Fig. 3.

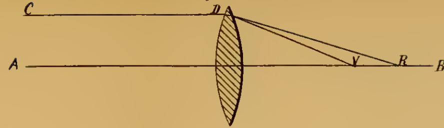


Fig. 4

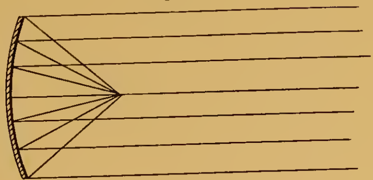


Fig. 5

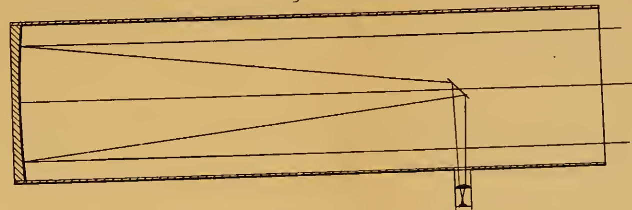


Fig. 6

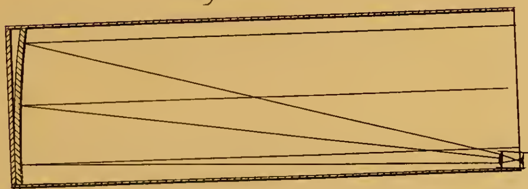


Fig. 7

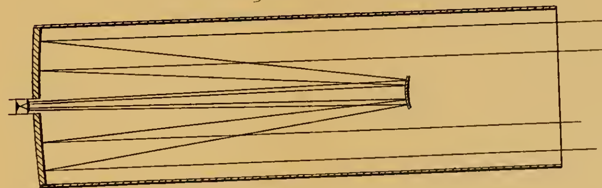
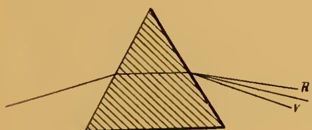
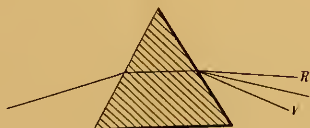


Fig. 8



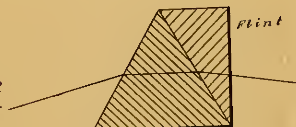
Crown

Fig. 9



Flint

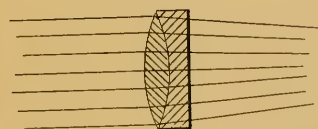
Fig. 10



Flint

Crown

Fig. 11



that sum for the interruption of our manufactures and commerce, which, therefore, will give us $320,000,000 in 1885. This gradual increase of loss, which will nearly average 20 per cent. per year, has no parallel in any other country. This is due,

First—To the poorly-constructed houses.

Second—To the rapid disappearance of small handicrafts, making room for the manufacturer by steam, with the use of high buildings and new modes of lighting.

Third—To the equipment of fire protection, which in its efficiency has failed to keep step with the manufácturer who daily introduces new elements of danger.

Fourth—To incendiarism.

Taking the constructions as they exist at present (which are erected to protect life and property), they are perfect fire traps. The space between ceiling and floor is left open, as well as the partitions lathed on both sides, the centre of which forms flues from cellar to roof, which, in case of a fire, convey the flames rapidly to all parts of the structure. Those vacant places are the abode of rats, which build their nests out of paper, cotton and matches, whenever these latter are within their reach, having a marked taste for phosphorus. This assertion will be corroborated by any contractor who has ever torn down an old building. Their nibbling often ignites those matches, and to this cause can be charged a number of our fires. Two per cent. additional cost would make this building fire-proof, noiseless and free from vermin.

If we take 10 per cent. of lime of fel, 10 per cent. of plaster of Paris, and 80 per cent. of refuse from the gas works or blast furnaces, the composition has only one-eighth the weight of brick, and three inches in thickness of this material will carry from 300 to 600 pounds to the square foot on a five-foot span. The application of this material can be made by any mechanic. Let the joists be laid in the usual way ; then at right angles lay pieces of 26 iron, one and a half inches wide, bent in a V shape ; nail these one foot apart in an inverted position ; then a section of board is fastened underneath to the joist by a screw hook. Mix the material with water, in proportion above given, to the consistency of cream, and pour one half inch over the board (centre) ; then this panel is done, and at the end of five minutes the panel can be removed to another section. Then a hollow box five feet long and width slightly tapering, but about two inches less than the space between joists, and in height one inch less than the joists, is placed upon the first horizontal coating, leaving one inch space on each side. This same material is then poured in between the box and the joists to the level of the box. A sharp knock at the smaller end of the box will immediately detach it from the composition. With a knife trim the top of the composition to an inch below the top of the joists. Then a slab one inch thick is placed vertically between the joist, forming a draft arrester at every five feet between joists. Then a slab molded elsewhere is placed over the edges, and the interstices of joists are filled with the same composition. Now the floor or tile can be laid, and the plastering done in the usual manner. The partition, regardless of height, can be made of the same material cast in hollow blocks four or five inches thick, with only one inch of material.

The cost of this material is not great, nor does it require skilled labor. We economize both bridging and lathing. It can be subjected to a white heat without losing any of its strength during the heat or after it. It preserves the wood and makes the structure fire-proof, as it excludes entirely the oxygen, without which combustion is impossible. The stairways and Mansard stones can be treated in a similar manner. In factories or store-houses, the hatchways, elevator holes and light shafts are the prime factors of our immense loss.

Those elevators should be built in fire-proof shafts, with oak doors covered with No. 26 iron and nailed at every three inches, having on their inner faces iron bars in bow shape, projecting inside of the shaft, which the car would force out upon its passage. The doors should be hung so as to close by gravitation.

Electric Light.—The dynamo machine should be entirely insulated from the ground. This can be done at a very little additional expense. The anchoring rods should be entirely inclosed in gutta-percha tube; then the foundation built around them, over which gutta percha or other non-combustible material should be laid; then the machine. The wires should not run parallel to each other, but start at as great an angle from the machine as possible. At every splicing of wire they should be soldered and insulated. No metallic staple should be used for their fastening, and metallic return circuit should always be used. The lamps should also be insulated and be closed at the bottom. A light wire, when a ground circuit is used, can set fire to a remote construction having a telephone, as there is no such thing as perfect insulation in wet weather. Should one of those wires come in contact with a telephone wire, it will run along this wire and fuse the magnet in the box, it being of very fine wire and offering great resistance. Should one of those wires fall to the ground, it would give a fatal shock to any one who should come in contact with it. If the machine is well insulated and a metallic return circuit is used, a naked wire may be handled with impunity.

Ashes.—There should be an ash pit where stoves are used, from the upper floor down to the ground, protected by self-closing iron doors on every floor.

Sidewalk Grating.—There should be a fine wire grating under all sidewalk openings, thus preventing lighted cigars from being thrown into the cellar.

Iron Shutters.—Iron shutters are objectionable; being heated on one side only, the expansion being unequal, they buckle; and although being arranged to open from the outside, when they are buckled it is impossible to work the latch.

Steam Pipes.—I am of the opinion that a steam pipe cannot ignite wood, unless the steam is superheated, but I do claim that very few boilers fail at times to furnish superheated steam. The boiler has now (a late introduction) a glass gauge, which is not altogether reliable, as it may choke with sediment and hold the water to a higher level than in the boiler. The test cocks are, therefore, still kept, and they may in some cases become unreliable. In the hands of a thorough engineer the boiler may foam, and his test will lead him to believe that he has water to his upper gauge, while, in fact, he has

none. A few minutes later he will find his boiler red hot, but as this is unknown to his employer (who, upon its discovery, would accuse him of carelessness, which he sometimes thinks himself guilty of), he banks his fires and with a trembling hand starts very slowly to replenish the boiler. During that period all the pipes in the building have been red hot; the fire has started and will immediately or soon destroy the building. If the pipes are free from any contact with combustible material, this danger may be obviated.

Theatres.—All theatres should have their floors filled with the composition that I have described, and the wall between the stage and the auditorium should be of brick and carried three feet above the roof. A gauze wire curtain should be run behind the "between acts" curtain, so as to assure its constant availability. All theatres hereafter erected should have means of exit upon all sides, and strong balconies with communicating stairways from one to the other. I do claim that escape ladders are of no avail to females, and that the best of firemen would have great difficulty in saving themselves if harnessed in female attire. The same outside escape should be provided for our crowded factories. The Western Union building now contains 360 operators on the fifth floor and two iron ladders are provided for them on one side only. Of that number 75 per cent. are young, feeble women, 50 per cent. of whom would roast alive before they could escape by those ladders.

Sprinklers.—A sprinkler has been lately introduced which, in my opinion, deserves the attention of our club. It consists of a tank placed on the roof with a gas-pipe leading from it to the ceiling, where a sprinkler head is attached. This sprinkler is soldered over with soft solder, which melts at 150° Fahrenheit. This tank has a floater-valve which opens when the level of the water is lowered, and allows the hydrant to replenish the tank (the tank is previously filled with a non-freezing liquid). One point is not very clear to my mind. In a three or four-story building, if the fire originates on the first floor, with our present hatch-holes, will not the heat be greater on the top floor than on the floor where it originated, thus melting the sprinkler head on the floors above, and not let go those where the fire originates?

In order to distinguish the location of the fire-alarm box, a piece of red glass could be placed on three sides of the city lamp the nearest to the box, and the post painted red; such lamp should be lighted every night regardless of the moon.

Cisterns could be built in the streets where the mains are inadequate or too far distant from valuable property, and filled partly by rains from the surrounding roofs or by hydrant water from the mains.

Each engine-house should have a well-hole through all floors, and also an extension on the roof, if additional height be required, and a simple pulley overhead to raise hose on the return from a fire, thus enabling it to dry by ventilating, at the same time furnishing immediately another set to reel up for readiness.

Linen hose is able to sustain a pressure of 200 lbs. to the square inch, and bursting is simply due to a rotten condition, caused by being constantly wet, and not by the pressure it receives from the engine. There are also contrivances in use in other cities by which bursted hose can be temporarily mended without stopping the working of the pumps.

TUNNELS AND INTERCEPTING SEWERS FOR THE SEWERAGE OF CLEVELAND.

BY J. H. SARGENT, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.
[Read September 9, 1884.]

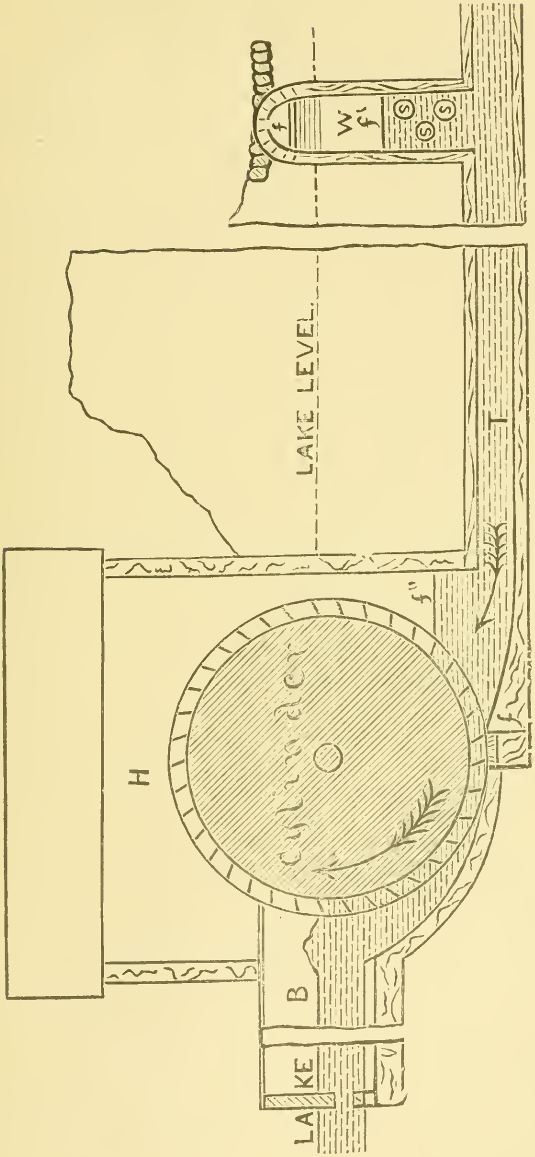
Again the people of Cleveland have their sereneness of mind disturbed, by the renewed irritation of their olfactory and optical nerves through the agency of our pellucid river. A goodly number of spontaneous engineers have sprung up to provide, as Mrs. Partington might say, "a fatal cure." On a former occasion I read before this Club a paper on the subject of drainage for the lowlands of our city; and now, at the risk of being thought cranky on the subject of water *vs.* filth with which to fill our harbors, I will restate the case in a somewhat different form.

The subject of the sewerage of Cleveland is one upon which I have spent much study, and I find it by no means difficult, but susceptible of a very satisfactory solution. In establishing a system of sewers for a city the first thing to provide is a suitable outfall. This in our lake cities is of course, the lakes themselves. It is of the first importance that the final discharge into the lake should be as far down stream as practicable, and it is fortunate for the city of Cleveland that this is also to the leeward of the prevailing winds.

For that portion of the uplands of the city east of the river, simple gravity will take all sewage into the lake below the city limits. But for the river flats and that part of the city west of them a different system is required, and this is what I propose to discuss.

For outfalls for all the sewage proper of this district, I would provide four wells, six or eight feet in diameter and 25 feet deep—one at the intersection of Eagle street and Central Way, one at Scranton avenue and Carter street, one at Center and Columbus, and one at Elm and West River streets. These I will call receiving wells; and I would connect all these wells by tunnels driven from the bottom thereof nearly or quite horizontal, say three feet in diameter, from West River to Scranton avenue, and four feet from the last to Central Way. And from this last I would drive a tunnel five feet in diameter direct to the north end of Murison street, where should be a discharging well or pit with an overflow into a flume or dock, in which should be carried the sewage out from the shore as far as may be necessary. This provides an outfall for the Walworth and Kingsbury Runs and all the sewage of both sides of the river below upper Central Way bridge. When it becomes necessary to relieve the flats above that, a branch tunnel will be run under Central Way as far as may be necessary.

Next, intercepting sewers only large enough to carry the ordinary every-day sewage should be constructed—one from Kingsbury Run and Broadway to the first well, one from Walworth Run, under Scranton avenue, and one from Columbus street under West River and Carter streets to


LAKE LEVEL.
H
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the second well, one from Centre street to the West River street well, and one from Superior street, South Water and Center streets to the Columbus street well. These intercepting sewers should be placed low enough to furnish drainage for the cellars on the flats where that is deemed necessary and which I provide for further on. Until then the sewage will rise in the receiving wells and fill the sewers to a point sufficiently above the water in the lake to furnish a head to carry it off. A head of six inches at the Central Way well would induce a velocity of one foot in a second in the tunnel ; one of two feet, a velocity of two feet—the head increasing as the square of the velocity.

The limit of this system with these dimensions will be a velocity of six feet per second, requiring a head of 18 feet and delivering 120 feet per second, which at one foot per hour for each inhabitant provides for more than 400,000 inhabitants. When this small section of the city has more than 400,000 people, they can well afford to spend an additional $100,000 to drive another tunnel. The main tunnel is 5,000 feet long and the branch is 3,500, and will cost not far from $150,000—based upon the actual cost of the shore end of the water-works tunnel. These figures Mr. Whitelaw can verify. The plan here presented is altogether self-operating, and I only refer to the use of power to show that its usefulness may be greatly extended without alteration in the original work.

I will now advance a little speculation as to the amount of sewage we have to provide for. Please to remember, in the outset, that all the rain-water and snow-water possible should be excluded from our intercepting sewers and tunnels. Then the sewage must reach them through the medium of the city water-works and the springs of the valley. The water-works maintained in 1883 an average velocity of one foot per second, which is of the same capacity as mine. We have to provide for perhaps half of the territory and half the population. It is hardly possible that the springs throw more water into the sewers and Runs than is evaporated by the steam engines, and used in fountains and in sprinkling streets, lawns and parks and is suffered to waste. This would leave us only a velocity of six inches in the tunnel A double supply and a double velocity would be even better for the works.

I have said that all the rain and snow water possible should be excluded from sewers and tunnel : and it is because all this is needed to maintain circulation in the river.

And now, gentlemen, with your indulgence, I will encroach a little upon the field of the mechanical engineer and explain the hieroglyphics upon the blackboard. *H* is the House that Jack Built, *W* is where he kept his liquor, *T* is the tap through which he drew it, and *B* is a basin in which to brew it. But dropping metaphor, I will explain, that here is the receiving well with the sewers *S* entering it; *f* is the surface of the sewage when left to be self-operating, and *f′* the surface when operated for under-drainage of the flats. From this well the tunnel conveys it to this flume. In this flume I would hang a cylinder, fitting its sides as near as may be, and resting on journals on a level with the ordinary stage of water in the lake.

The cylinder would be, say 40 feet in diameter and 10 feet long, and have buckets one foot wide, set somewhat eccentric with the face of the

wheel for perfect clearance as they leave the water. At the bottom of the wheel is a mud-sill, giving as little clearance as possible between it and the buckets. It will be somewhat wider than the space between them. These buckets are half the cross-section of the tunnel, and one revolution per minute will induce a velocity of one foot per second in the tunnel; discharging into the lake twenty cubic feet of sewage every second of time.

I will now pursue this fragrant mass further: Beyond the cylinder I would enlarge the flume to a cross-section of say six times that of the tunnel, 20 feet wide and six feet deep, and carry it three hundred feet into the lake. I would then give the material a half hour to settle. I would have the flume carried up eight feet above the water to break the seas. Its outer end would be closed from above to a foot below water, and from below to within a foot of this, thus leaving a foot opening below water. This is to arrest anything that might float to the surface or subside in this half hour, to be dredged out for the farmers' use as often as may be required.

As the quantity of sewage increases this basin system may be extended if found to work well. The flume will be floored over and made as nearly air-tight as practicable, and ventilated only through the furnace of the engine, that the foul gases may be consumed.

Now to meet the views of those well-meaning people who propose to meet the difficulty by transferring the lake to the other end of the river, all we have to do is to reverse the engine and the thing is done. The lake water flows back to the wells, and taking the sewage with it, overflows into the river, through which in a week or two it would reach the harbor of refuge—where all may be saved and stored, an ample ration—a garden of roses, to tickle the noses of the coming generation.

Now, gentlemen, I thank you for patiently listening to a few of my ponderings upon this question. It is a relief to me to unload them to make room for other freight. I have sandwiched it in, as it were, among other things demanding all my attention, and hope the gentlemen present will not spare the gray locks, but feel at liberty to catechise and criticise to their heart's content.

In conclusion I will say that, being myself on the retired list—out of the market—it can hardly be thought immodest for me to say that I do not think it necessary for our city to go abroad for engineering talent to cope with this subject. So far, home talent has been able to give us our sewers, our streets, our water-works and our Viaduct; and it is humiliating to our city and our club to say that neither is equal to a solution of the simple question before us.

NOTE ON LOWERING A LARGE WATER MAIN WHILE IN USE.

By S. Bent Russell, Member St. Louis Engineers' Club.
[Read Dec. 3, 1884.*]

The pipe that was lowered leads from the stand-pipe of the St. Louis water-works to the centre of the city and considerably more than half the water consumed by the city passes through this pipe at the point of lowering. The grade of 20th street in the two blocks between Benton street and Maiden Lane having been changed by ordinance, it became necessary that the grade of the pipe between these points should also be changed. The pipe is of cast iron in twelve foot lengths, thirty-six inches inside diameter, with sockets or bells five inches deep. Pipes were joined by the ordinary lead and gasket. A pipe length when full of water will weigh about 11,000 pounds. A deflection of four inches in one pipe length will open or draw the joint about one inch.

The old grade of 20th street had a summit at North Market street, which lies half way between Benton street and Maiden Lane, while the new grade has a depression at this point. The greatest lowering required was at this place and amounted to 6.3 feet.

To produce the least possible motion in every joint the final bed of the pipe was laid out in vertical reversed curves. The total fall of each pipe having been determined, the fall for each pipe in any partial lowering was taken with a certain ratio to its total fall. The pipe was lowered in five stages, being one-tenth, two-tenths, two-tenths, one-fourth and one-fourth respectively. Each temporary bed of the pipe was carefully graded under the pipe and of the full width of the trench, leaving under each pipe immediately behind the bell a bench three to four feet long. The benches were then removed with the pick by working them out from the top, not allowing any one of them to be cut away much faster than the others. As soon as the pipe touched the temporary bed, lowering stopped and a new bed was prepared. On the final bed, blocks, eight inches by six inches, and four feet long, were set to grade, and as soon as the pipes rested on them wedges were driven between the blocks and the pipes. Removing the benches in the last lowering occupied about an hour and a half, and nearly a day was taken for each stage of the work. About fifty-four pipes in all were lowered.

The pressure in the pipe was about thirty-five pounds to the square inch, and the pipe was not shut off, but continued supplying the city during the operation. The pipe line, before the work, was slightly distorted by settling. In plan it contained a slight reverse curve. The curvature was made greater as the pipe was lowered the first three stages, and during the last two it was forced towards the straight line again. The irregularities in the profile were corrected gradually as the pipe came down.

No joint was drawn a half inch during the work, and no pipes were broken. No leaks other than a very slight sweating of the joints occurred.

The work was completed Nov. 30th, 1884.

* Written after remarks by Mr. Whitman, Dec. 4, 1884. See minutes.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

DECEMBER 17, 1884 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P. M.

President George L. Vose in the chair, twenty-eight members and two visitors present. The record of the last meeting was read and approved.

Mr. Arthur H. Howland was proposed for membership, recommended by Messrs. F. P. Stearns and S. Perkins.

Mr. Alex. L. Kidd was proposed for membership, recommended by Messrs. Thomas J. Young and W. H. Bradley.

Mr. James W. Sewall was elected a member of the Society.

C. W. Raymond, Major of Engineers, U. S. A., read a paper on the "Anchorage Capabilities of Harbors of Refuge."

Mr. A. E. Burton read a paper on the "Quincy Granite Railway."

The Society was invited to attend the meeting of the Society of Arts on Thursday evening, January 8, 1885, by George F. Swain, its Secretary, when Major C. W Raymond would read a paper on Boston Harbor.

H. L. EATON, Secretary.

[*Adjourned.*]

JANUARY 14, 1885 :—A special meeting of the Boston Society of Civil Engineers was held, and called to order at 7:40 P. M.

President George L. Vose in the chair, twenty-one members and four visitors present. The reading of the record of the last meeting was postponed one week.

Mr. Clemens Herschel read a paper on the River and Harbor Bills of the U. S. Congress.

Discussion followed by Messrs. Mitchell, Raymond, Carson and Brook.

H. L. EATON, Secretary.

[*Adjourned.*]

ENGINEERS' CLUB OF ST. LOUIS.

JANUARY 21, 1885 :—The Club was called to order at 8:15 P. M. at the Mercantile Club Rooms, President Robert Moore in the chair, 24 members being present.

The reading of the minutes of last meeting was dispensed with. The President reported a letter from the Librarian of Mercantile Library in regard to Scientific Works.

The following gentlemen were proposed for membership : Messrs. F. B. Maltby, by J. A. Ockerson and J. B. Johnson ; A. J. Sypher, by W. B. Potter and E. A. Engler ; John G. Kelly, by Ed. Flad and G. Bagnall.

Mr. W. Bouton then read a paper on "Elimination of Errors in Field Work," which was discussed by Messrs. Johnson, Holman and Constable.

Mr. Howard Constable then read a paper on "Water Meters," exhibiting a variety of meters. This paper was generally discussed.

Mr. Melcher exhibited a copy of "Steam Making" by the late Prof. Chas. A. Smith, which has just been published.

THOS. D. MILLER, Secretary.

[*Adjourned.*]

IN MEMORIAM.—PROF. C. A. SMITH, LATE SECRETARY OF THE ENGINEERS' CLUB OF ST. LOUIS.

At the meeting of the St. Louis Engineers' Club, held Dec. 17, 1884, Prof. C. M. Woodward, on retiring from the presidency, spoke as follows :

[President Robert Moore had just taken his seat.]

Mr. President—It occurs to me that the records of the year now closing should contain a more detailed notice of Prof. Smith than is shown on our minutes. My relations to Prof. Smith were most intimate for 23 years ; hence I can speak from a knowledge which no other member of this club possesses. I submit the following brief sketch of his life and character :

Charles A. Smith was born in St. Louis, Oct. 1, 1846. His parents were both Massachusetts people, who had been still further west. From both father and mother he inherited the instincts of a sailor, and the blood of several generations of shipmasters coursed through his veins. Though he never became a sailor, he always showed a sailor's fondness for "fixing things," for using his hands, for actual construction.

While he was yet an infant, his mother died of cholera in St. Louis, and he was placed in the care of his father's sister in Newburyport, Mass. This kind aunt was his mother, and her house was his home till he had a home of his own. His mode of life was simple and plain, but young Smith made warm friends, and his boyhood was happy. I first met him in 1860, when I became principal of the Boys' High School of Newburport. He was then fourteen years old and a member of the second class. He was a pleasant little fellow, with a frank, earnest look, and a forehead which suggested brains. When the school gave expression to its loyalty to the Union by the erection of a liberty pole and publicly celebrated a flag-raising, young Smith was selected by his schoolmates to mount the platform and haul home the Stars and Stripes.

The school had a very good theodolite, and when we came to Loomis's Surveying, a great enthusiasm for field work was developed, and young Smith was never so happy as when on a surveying party. He took the English course and graduated in 1862. The next spring he went into the office of J. B. Henck, Civ. Eng., in Boston. At that time he probably had no idea of going to an engineering school. In 1864 he was leveler on the Boston, Hartford & Erie Railway. In 1865 he became chief assistant in the City Engineer's office, Springfield, Mass. By this time he saw clearly that an engineer requires a training far beyond a high-school education, and he resolved to enter the Mass. Institute of Technology, then first opened. He had been reading ahead somewhat, with occasional help from me, so that he entered what was organized as a sophomore class. He lived again in Newburyport, and went 80 miles daily on his way to and from the Institute. President Rogers was his teacher in physics, Prof. Runkle in mathematics and applied mechanics, and Prof. Henck in civil engineering.

He graduated in the pioneer class in 1868. I never quite understood how he managed to meet the cost of his course at the Institute. To be sure, he had carefully saved the earnings of three years, and he secured for his vacations most excellent employment under the celebrated

hydraulic engineer, J. B. Francis, at Lowell, Mass. He there assisted in determining the flow of water in pipes, over weirs, the efficiency of turbines, etc. I left Massachusetts for St. Louis in 1865, so I did not follow closely his career as a student.

After a year as engineer on the Union Pacific Railway in Utah, he returned, on the completion of the road, to Boston and went into partnership with Prof. J. B. Henck, as civil engineers. While thus associated with Prof. Henck, he took charge of the Blue Ridge Railway of North Carolina, as division engineer.

At that time, in 1870, the steady development of the Polytechnic School of Washington University made it necessary to appoint an instructor of civil engineering. I took pleasure in recommending young Smith for the position, and he was appointed. For the first year he made his home in my family, and as a preparation for the work of the class room he read with me Rankine's Civil Engineering entire. After a brief experience as instructor, Mr. Smith was appointed professor to the chair of Civil and Mechanical Engineering, which was subsequently named in honor of William Palm. This chair Prof. Smith held till June, 1883, when compelled by his last illness to resign.

Though devoted at all times to the work of his professorship, Prof. Smith found time to mingle in matters of practical engineering. For five years he was consulting engineer of the Iron Mountain Railway, among other things designing the De Soto shops, and building a new pier in the Black River. In a similar way he was associated with Messrs. Shickle, Harrison & Co., designing the arched ribs of the roof over the Chamber of Commerce, and the iron trestles of the Bessemer Iron Works. Prof. Smith was engaged as consulting engineer for the construction of the water works of Hannibal, of St. Charles in Missouri, and of Amesbury, Mass. His last professional duties were in connection with the last named. The pumping works at Richmond, Va., were designed by him, his plans being entered in competition and receiving the first prize. In 1879 he spent his summer vacation as resident engineer of the Baltimore Bridge Co., building piers in the Mississippi River just below Minneapolis.

Without attempting to give a full list of the professional enterprises of Prof. Smith, I have said enough to show how tireless a worker he was, and how closely he studied the practical details of engineering. But it was in connection with this club that his devotion and enthusiasm were most fully shown. He was an active member for twelve years, and the secretary for nine or ten years. The club has not always been as flourishing as it is now. It has had its seasons of depression, when only the zeal and the courage of Secretary Smith seemed to hold it together. Nothing but the direst necessity compelled him to yield at last.

The fatal malady which, in the shape of a cancerous tumor, brought his life to an untimely close on the 2d of Feb., 1884, was born, as he thought, of hard work, of exposure, and of physical neglect. He could scarcely stop to eat or sleep ; it was work first and comfort last.

Nothing in Prof. Smith's life was more heroic than the way he battled for two years against an impending fate. When too weak to stand before his class, he taught reclining upon a lounge. One of his last

pupils speaks, in a notice of his beloved professor, of "the days of suffering spent in his study in the university, when we gathered round him as he lay on the lounge, unable to stand, and listened to his exposition of 'Economic Location,' taking as a basis the work of his friend Arthur Wellington."

In January, 1883, he was forced to give up his class work altogether, and to keep his room. Still, he was not idle. Lying on the bed or reclining in an easy chair, he was hard at work upon his two books, "Steam Making" and "Steam Using," which are just now being issued from the press of the *American Engineer*, in Chicago. The first was finished by the end of 1882. and arrangements were made for its publication; but the prospect for the second book was gloomy enough. Nevertheless, he worked at it with a terrible earnestness which no unfavorable symptom could diminish. Nay, though clinging to the faintest glimmer of hope of returning health, he toiled at his book with the resolute air of one who was fully conscious that his days were numbered, and that the book must speedily be finished. In spite of pain and the dark shadow of the inevitable, his mind seemed clear and his hand steady. In the spring of 1883 he moved back to Newburyport, Mass., to be near his physician and his family friends. There, in a quaint old house, in a quiet neighborhood of that quiet town, he finished his book, laying down his pen and the burden of life at the same time. The readers of "Steam Using" may be glad to know that the author's very life's blood went into that book—that it was the last, the most perfect fruit of a very active and noble life.

Prof. Smith is a good example of a poor boy who made his own way, who fought his own battles, who earned and honored every position he took. He was always a student. Some of you will remember with what enthusiasm he studied Quaternions and Thermodynamics; with what zeal and success he read all that he could get on Graphical Statics, and how many important additions he suggested. The records of this club probably will show that Prof. Smith has presented more papers than any other member, past or present.

As an engineer, Prof. Smith was bold and trustworthy. His confidence was based upon sound theory and careful practice. He was skillful in preparing estimates, and was always well informed, both as regards the latest improvements in engineering and the best methods of working the materials of construction.

These accomplishments added greatly to his value as instructor of young engineers. His students were brought very close to engineering work. Though well read in theory, he loved to dwell on the details of practice. He never lost an opportunity to learn a new process, or to study a new machine. He used to tell how, while resident engineer on a road in New England, he tried his hand on the engine of the construction train till he was able to "stoke" and to "drive."

Prof. Smith left a wife and three children. During her husband's long and discouraging sickness, Mrs. Smith was better than a faithful nurse; she brought aid to his self-imposed labor, and hope and cheer to his fainting spirit. So well did she understand the nature of his work and his needs, and so helpful was the assistance she brought, that it is not too much to say that without her positive co-operation and encouragement,

the two books which he leaves behind would never have been finished.

I will not speak of personal losses. I prefer to feel that we all had much to be thankful for in Prof. Smith, and the nearest had the most. Though dying in his 38th year, Prof. Smith's memory may well be preserved; the world is certainly the better for his having lived in it.

FEBRUARY 4, 1885.—The Club was called to order at 8 P. M., Vice-President McMath in the chair, thirty members being present. The minutes of the last two meetings were read and approved.

The Executive Committee reported the names of the following gentlemen, who were unanimously elected: C. W. Clarke, E. L. Foot, F. B. Maltby, A. J. Sypher and John G. Kelly.

The Secretary reported receipt of a copy of "Steam-making, or Boiler Practice," the donation of the publishers *The American Engineer*. On motion, the Secretary was instructed to extend the thanks of the Club to *The American Engineer* for the valuable addition to the Club's library.

The following gentlemen were proposed for membership: D. E. Condon, by M. L. Holman and S. B. Russell; John T. Desmond, by J. A. Ockerson and R. E. McMath; Preston M. Bruner, by W. B. Potter and E. A. Engler.

Mr. Wm. Wise then read a paper on "Mill Creek Sewer," which was discussed by Messrs. Ockerson, Holman, Sedden, Whitman, Woodward and H. C. Moore.

Mr. J. B. Johnson presented discussions of creeping of rails, by Mr. Theodore Cooper, of New York, and Mr. John A. Wilson, of Philadelphia.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

FEBRUARY 3, 1885.—The 202d meeting was held at 4 P. M.

President Williams in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Wright read a paper, the "Ventilation of Stables."

The Secretary read a letter from Vice-President Chanute, containing several suggestions for increasing the efficiency of the Society.

It was voted that these recommendations be referred to a committee, which should report at the next meeting.

The President appointed Messrs. Morehouse, Artingstall and Wright as this committee.

Mr. Cregier offered the following, which was adopted by a rising vote:

Resolved, That this Society has heard with profound regret of the death of the late John B. Jervis, whose eminence in the domain of engineering and long and successful service has endeared him to the profession everywhere.

Resolved, As a token of respect to the memory of the distinguished dead, that this resolution be entered upon our records.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

ENGINEERS' CLUB OF MINNESOTA.

JANUARY 9, 1885.—Regular Meeting. The Club was called to order by the President, eight members being present.

In the absence of the Secretary, the reading of the minutes was dispensed with, and E. T. Abbott was appointed Secretary pro tem. As a number of members were necessarily absent, it was voted to hold an adjourned meeting on Friday, Jan. 16, at which time the election of officers was to be the special order of business.

Mr. W. S. Dawley was proposed for membership by Messrs. de la Barre and Angst.

At this meeting several books and other articles were presented to the Club, for which the Secretary was directed to return thanks. The Club then adjourned for one week.

E. T. ABBOTT, Secretary pro tem.

JANUARY 16, 1885.—Adjourned meeting. The club was called to order by the Vice-President, ten members being present.

The records of the last two meetings were read and approved. Several letters relating to the library of the club were read by the Secretary. Mr. John T. Baker was elected a member of the club.

The club then proceeded to the election of officers, with the following result:

President—George W. Cooley.

Vice-President—E. T. Abbott.

Secretary and Treasurer—Wm. A. Pike.

Librarian—Wm. W. Redfield.

Before electing a secretary it was voted, that in view of the great amount of work falling upon the Secretary, that he be exempt from all dues and assessments.

The Secretary was directed to notify all members in arrears and request remittances. Voted to request the President to prepare a list of committees on various engineering subjects, to be presented at the next meeting.

Mr. de la Barre extended an invitation to the club to attend the starting of the steam machinery of the Washburn mill, to take place February 25th.

[*Adjourned.*] WM. A. PIKE, Secretary.

FEBRUARY 13, 1885:—Regular meeting. The Club was called to order by the President, who soon gave the chair to the Vice-President. There were present ten members.

The annual report, including that of the Treasurer, was read and accepted, and Mr. Abbott was elected Auditor. Voted to publish the report in the JOURNAL.

The following committees for the year were announced by the President, it being understood that at the next meeting these committees would be assigned times when they would be expected to furnish reports or papers:

Finance—Pike, Abbott, Rinker.

Library—The Librarian, President and Vice-President.

Bridges—Angst, Van Duyee, Kendrick, Waitt.

Railroads and Transportation—Rhame, Rich, Angst.

Materials—Pike, Kees, Carr.

Sewers and Drainage—Van Duyee, Rinker, J. T. Baker.

Engineering Jurisprudence—Abbott, Rinker, Sprague.

Buildings—Kees, De la Barre, Libby.

Rivers and Canals—De la Barre, Newman, Brooks.

Streets and Paving—Rinker, Pike, Rhame.

Surveying and Topography—Plummer, Chapman, Foss.

Weights and Measures—Redfield, Abbott, Carr.

Machinery—Waters, Woolsey, Redfield.

Mines and Mining—Libby, Pell, Woolsey.

Water Supply and Rainfall—Sturtevant, Waters, Foss.

The Club also voted to add the following committees, which were referred to the President to fill:

Lighting, Heating and Ventilation; *Electrical Engineering*, and a committee on miscellaneous engineering subjects not covered by above list.

Mr. W. S. Dawley was elected a member of the club, and the following gentlemen proposed for membership: D. P. Waters, by Messrs. Cooley and Abbott;

Walter Pardee, by Messrs. Cooley and Pike, and F. H. Todd, by Messrs. Sturtevant and Pike.

The Secretary reported the donation of a number of books to the library, and the Committee on Library was directed to prepare rules to govern its use.

Mr. de la Barre then gave details of bids for building a plate-iron bridge over the canal, received by the Minneapolis Mill Co.

Voted to devote the next regular meeting of the Club to the discussion of the proposed new bridges across the Mississippi River at this place.

[*Adjourned.*] WM. A. PIKE, Secretary.

ANNUAL REPORT OF THE GOVERNMENT OF THE ENGINEERS' CLUB OF MINNESOTA FOR 1884.

Gentlemen: It was our misfortune to be unable to report at the regular annual meeting set apart for the election of officers and the installation of a new government, and in presenting at this late day the annual report, in accordance with a requirement of the constitution, we ask your kind indulgence and benevolence.

A short history of the formation of this Club was given by our predecessors in office, in their annual report; and as the facts in the case are well known to most of you, we abstain from a repetition, and ask your attention to other matters and items.

When our term of office commenced, the meetings of the Club were held in the rooms of the Academy of Natural Sciences, and most of you will remember the difficulties under which we assembled. The light furnished us was at first very primitive; but at the request of the Club it was changed to brilliant Minneapolis gas, such as it is. The arrangements for heating were also of a low order, and several of our number made characteristic studies on the combustion of fuel, with special reference to pine slabs. There were no papers read on the subject, but we believe that several of the members made heavy gains in knowledge and experience.

Another obstacle to enjoyment of the privileges of the rooms of the academy was the one key held by one member, whose absence or tardiness caused delay and vexations which resulted in several curb-stone meetings.

Last, but not least, the condition of our treasury demanded a curtailing of running expenses, and after four months the club again changed its place of meeting to the committee rooms of the City Council, obtained through the kindness of Mr. Rinker, our ex-president.

Several committees were at different times appointed to look up rooms, but their efforts did not culminate in success until nearly the end of the year, when the comfortable and well-located room in which we meet this evening was secured, mainly through the efforts of Messrs. Abbott and Cooley, to whom the club is indebted. Several of the members have made handsome donations for the furnishing of the room, and we now have a home. Our library has been started, and with the good-will and earnest work of our members we shall not fail to collect in time a respectable and valuable collection of books and papers.

The government of the Club for the past year has done its best to bring about success, after several failures, and we trust the result may be satisfactory to all concerned.

The membership of the Club has been increased by the election of the following gentlemen, viz.: Messrs. Newman, Rich, Woolsey, Pell, Plummer, Libby, Carr, Barrington and Brooks, and it is hoped that by the end of the current year we will have attained a membership of not less than fifty.

The Club enjoyed, during the year, several meetings at the residences of members, where the evenings were spent in a social and pleasant manner, adding attractions to our Club which brought out some of our most busy members.

The most important and commendable actions of the club during the year were

its joining of the Association of Engineering Societies, and the publication of our papers in the JOURNAL of the Association, and it is hoped that through this means we may get into closer communication and relation with other engineering societies.

In this connection it is proper to say that the papers read at the Club were limited in number, and we earnestly recommend that every effort be made to have papers at every regular meeting It is true that most of us are so occupied with the labors and duties of our profession, that we have but little spare time to devote to the often tedious task of preparing a paper ; yet we all have at different seasons more or less idle time, which should be given to our advancement and that of our profession ; and how can this be better done than by the careful and conscientious preparation of a paper to be read to our brother engineers ?

During the months of September and October no meetings were held, owing to the absence of many members, and it is with a view to such circumstances which may reduce the number of meetings in any year to less than the number of months, that we earnestly recommend the holding of semi-monthly meetings. Papers may only be read at the monthly meetings, while at the others the Club could occupy itself with the reading and discussion of articles in engineering and scientific periodicals, or with the discussion of public or city affairs, into which engineering or scientific features might enter.

During the approaching spring and summer seasons we would urge the Club to arrange and carry out excursions to visit *in corpore* some of our public and private institutions and works. At these excursions one of the members should act as guide and another as reporter, the report being read and discussed at the following Club meeting.

By discussing in the ways above indicated affairs of a public nature involving engineering questions, we may be able to earn for our club a certain prominence in the estimation of our fellow-citizens, which would be acceptable to all concerned, and in this manner become a valuable and respected body doing good service for our commonwealth.

Thanking you for your confidence and patience, we are

Yours very respectfully,

W. DE LA BARRE, President.
GEO. W. COOLEY, Vice-President.
WM. A. PIKE, Secretary and Treasurer.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. IV. March, 1885. No. 5.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE SEPARATE *VERSUS* THE COMBINED SYSTEM OF SEWERAGE,

AS EXEMPLIFIED IN THE DRAINAGE OF HYDE PARK.

BY BENEZETTE WILLIAMS, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read February 17, 1885.]

Since the completion, six months ago, of the report upon the Drainage and Sewerage of Hyde Park, made by Mr. Cole and myself to the Board of Trustees of the village, it has been our intention—as the members of the Committee on Drainage—to bring to your notice some of the features of the plan proposed for that part of the village generally known as the Calumet region. This task having devolved upon me, it has been deferred from month to month, with the hope of having more time at my disposal.

On consideration, I have concluded to extend the scope of the undertaking somewhat beyond the mere description of the proposed plan. The reasons for this are that it holds an important relation to the general questions arising between the respective advocates of the separate and combined systems of sewerage, as well as to some of the special questions raised with reference to the sewerage of Kansas City that was discussed in a very interesting and able manner before the Engineers' Club of St. Louis by a member of that club, Mr. Robert Moore, and an honored member of our society, Mr. Chanute. This discussion was published in Volume III. of the JOURNAL of the Association of Engineering Societies.

The description of the Hyde Park plan will be facilitated by making an abstract of the report, which will partly consist of appropriate quotations therefrom.

Hyde Park, a municipality organized as a village under the laws of the State of Illinois, has an area of about 48 square miles, twelve more than the city of Chicago. It is twelve and one-quarter miles long from north to south. The lakes, Calumet, Hyde, and Wolf, in the southern half of the village, have a combined area of about five and one-half square miles. They are connected with Lake Michigan by the Calumet River, which has a total length of twelve miles within the village. The mouth of this river

is six and one-half miles distant from the inlet of Calumet Lake, and eight miles from the junction of the two branches, which together have a watershed of about 450 square miles. Its depth varies from eight to fifteen feet, and that of the lakes from one to six feet at ordinary stages of the water.

The most notable geological feature is an outcropping of lime rock in a ridge called Stony Island, about one mile north of Lake Calumet. This ridge trends in a northeasterly direction to Lake Michigan, with occasional outcroppings. Elsewhere throughout this region the bed rock is overlaid with drift clay of varying thickness, and this is again covered with sand to a depth of from one to eighteen feet, except over a strip of territory west and north of Lake Calumet, between Ninety-fifth street and One Hundred and Thirtieth street, where the clay is bare.

Hyde Park is made up of many scattered communities, as South Chicago, Grand Crossing, Woodlawn, Pullman, Kensington, Cummings, Colehour, Roseland, Riverdale, and Hegewisch, all being south of Fifty-ninth street. The northern part of the village, from Thirty-ninth to Fifty-ninth street, is but the extension of the City of Chicago in its manner of growth. In 1880, the population of the village was 15,724, though it now probably exceeds 50,000.

Pullman alone had a population of 8,513 last October, all of which has been added since 1880.

The Calumet region offers unsurpassed facilities for manufacturing and shipping, the Calumet Harbor being second to none on the lakes. Ten trunk lines of railroad find entrance to Chicago across this portion of Hyde Park, and the Western Ind. Belt road brings all others centring in Chicago into close connection with it.

The territory north of Fifty-ninth street has main sewers, constructed on the combined system, discharging into Lake Michigan, the ground lying sufficiently high for such a system.

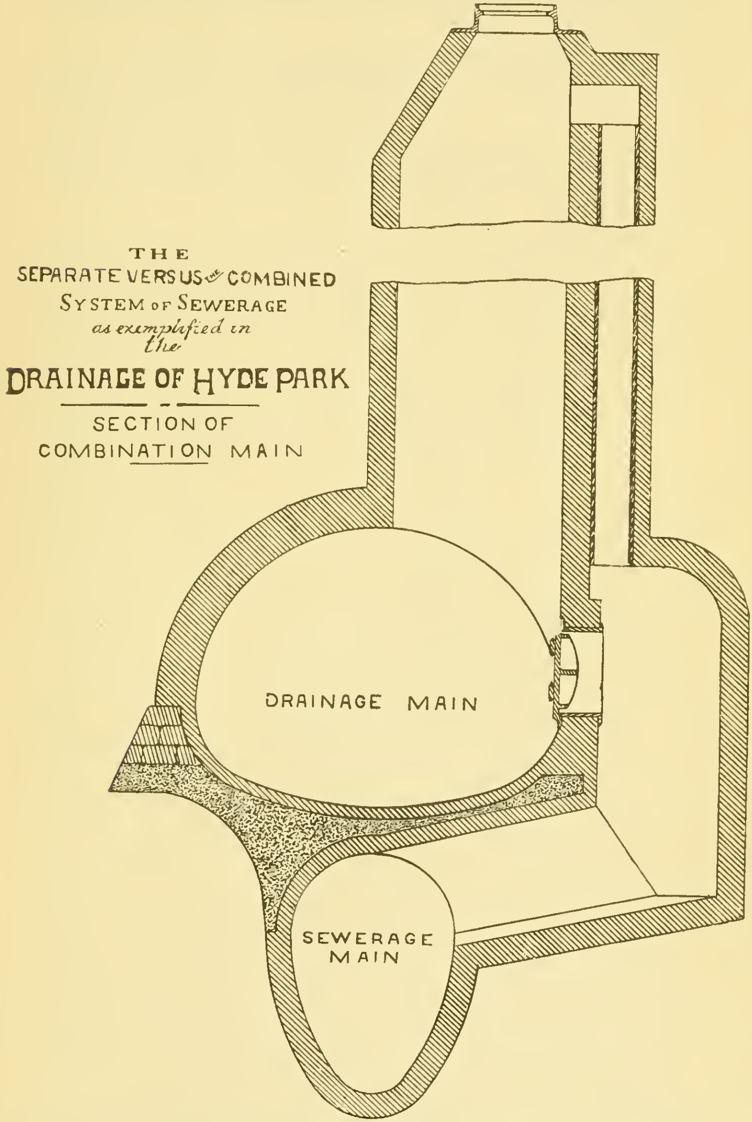
As will be seen on the map, the territory south of Fifty-ninth street has been divided into three districts.

The Pullman district, comprising the territory west of Lake Calumet and including the communities of Pullman, Kensington, Roseland and Riverdale, has an area of about seven square miles, and is for the most part so high and so accessible, to both lake and river, as to be readily drained by gravity. Pullman proper already has a system of storm-water drains discharging into the lake, and a separate system of sewerage extending to all buildings in the town.

The Hyde Lake district, comprising all east of Lake Calumet, and south of the proposed ship canal at Cummings and One Hundred and Fourteenth street east of the river, has an area of about six and one-half square miles, exclusive of the lakes, and is for the most part marsh land. Whenever drainage is required, an extension of the methods employed in the district yet to be considered will be suitable for this. At present, the only improvements in this district are those now in process of erection at Hegewisch by the United States Rolling Stock Company.

The Central district, comprising all the territory north of those already mentioned, and south of Fifty-ninth street, extending from Lake Michigan to State street, contains, exclusive of park lands, an area of twenty-two and one-fourth square miles. It includes the flourishing communities

of South Chicago, Colehour, Grand Crossing, Cummings and Woodlawn, besides many scattered dwellings. This district is the one most immediately in need of drainage, for, besides being very flat and low, it receives upon its surface the storm waters of an area of twelve square



miles extent, from outside its own limits, lying in the towns of Lake and Calumet. Nearly all of the outside territory has an elevation of from twelve feet to ninety-five feet above datum.

The average elevation of the whole territory of 22¼ square miles in the

Central district, including the Stony Island Ridge, is 6 feet above datum. The average elevation of more than one half of the district is only 4.2 feet above datum. The site occupied by South Chicago has an elevation of 4.5 feet. The average elevation of Section 26 in which Grand Crossing is located is 5.7 feet. The average elevation of Section 35, immediately south of Section 26, is 4.2. feet

The records kept by the city of Chicago from 1854 to 1883, inclusive, show that for the whole period of thirty years the average level of Lake Michigan has been 1.9 feet. The average level for two years, 1858 and 1859, was 3 feet. The average for 1876 was 2.6 feet, and for 1883 2.4 feet. The highest monthly average was 3.8 feet, and the highest daily average 4.7 feet. Under the influence of winds the lake has sometimes reached the height of six feet.

The report recommends the establishment of two pumping stations for the Central district, located as shown on the map ; and that storm water and sewage be kept separate, and both pumped. The storm water from the Grand Crossing station to be pumped into an open drainage ditch, extending on the line shown, from Lake Calumet to State street, which ditch is to receive by gravity all the drainage from 12 square miles of territory west of the village : that from the South Chicago station being pumped into the Calumet River ; the sewage from each station being pumped on to land that may hereafter be selected, for the purpose of purification.

The figures given above show that for thirty years Lake Michigan has had an average height of only 4.1 feet lower than the average of this district ; that its greatest recorded yearly average has been but 3 feet lower, its greatest recorded monthly average but 2.2 feet lower. and its greatest daily average but 1.3 feet lower than the district. Hence, the impossibility of draining it by natural means is apparent, unless the surface should be raised a sufficient amount for the purpose, as has been done in portions of Chicago, and as has been attempted at South Chicago during the last few years. To adopt the plan of raising the streets, the report considers, would be exceedingly detrimental to the interests of the village in many ways, beside being more expensive. Those who would cite Chicago in justification of the adoption of such a plan are referred to the following comparison between the two cases : The average natural height of the 36 square miles comprised within the present corporate limits of Chicago was about 13 feet above datum, while the 22¼ square miles in the Central district of Hyde Park have an elevation of only 6 feet. Only 13 square miles of Chicago were less than 10 feet above datum, and these had an average of height of 8.5. About the same area in the Central district of Hyde Park has an elevation of 4.2 feet. Twenty-three square miles of Chicago lie between 10 and 25 feet, having an average of 16 feet. The greatest distance that it is necessary to drain in Chicago is about 3½ miles, with the ground at the furthest extremity 25 feet above datum. In Hyde Park much of the land four miles from either lake has an elevation of only six or seven feet above datum, and one extensive tract which is more than two miles from the lake has an elevation of only one or two feet above datum. In Chicago the lowest tracts—which in but very few places fell as low as six feet—were adjacent to the river.

If the total amount of filling which has been deemed necessary for Chicago was spread over its whole area, we estimate that it would not amount to more than two feet. If the portion of Hyde Park under consideration should have one deep open channel cut through it at about Eighty-third street, and the ground raised ten feet over the whole territory. it would possess no better facilities for drainage than Chicago with the radiating branches of its river, and its streets filled as has been done. The amount of filling required to do this would be five times what has been done in Chicago.

The pollution of the Chicago River has become so great, that expensive works have been carried out for its purification, though five miles of it are still left in an exceedingly foul condition.

These works are the deepening of the Illinois and Michigan Canal, the Fullerton Avenue conduit, and the new canal pumping works, which have cost as follows:

From 1866 to 1871, the deepening of the Illinois and Michigan Canal	$3,300,883.71
From 1874 to 1878, the Fullerton Avenue conduit, about....	575,000.00
From 1881 to 1883, the New Canal Pumping Works	275,576.20
Total....	$4,151,459.91

The expense of deepening the Illinois and Michigan Canal, though originally borne by the city, was finally paid by the State.

The rated capacity of the two pumping works is as follows:

Fullerton Avenue works....	1,440,000	cubic	feet	per hour,	4	feet high.
New Canal Works....	3,600,000	"	"	"	8	"
Or reduced to an equivalent of 1 foot high:						
Fullerton Avenue Works....	5,760,000	"	"	"	1	"
New Canal Works....	28,800,000	"	"	"	1	"
Total....	34,560,000	"	"	"	1	"

Assuming that the pumps, when in operation, perform but one third of their rated work, we have about 12 millions of cubic feet per hour one foot high. or an annual work of 105,120 millions of cubic feet one foot high, as the work done by them. This is equivalent to pumping $\frac{3}{5}$ of the annual rainfall—which amounts to 25 inches—from 36 square miles of territory, and 3,415 millions of cubic feet of sewage 19 feet high. These figures are given to show that even in Chicago, where the reasons for such a course are far less than in Hyde Park, the plan of universal pumping of the sewage and storm water would not have been much or any more expensive than the plan that has been adopted.

For storm-water drainage it is proposed ultimately to conduct the water to the two pumping stations through underground systems of conduits, one main conduit being so located as to connect the two pumping stations, and to afford a means of flushing the main drainage ditch throughout its whole length. It is proposed that lateral drains should be built only on East and West streets, thus bringing them generally one eighth of one mile apart, and that they should be built without house connections—unless it may be with down spouts outside of the houses. The ground being almost uniformly level, should such a system be overcharged, the water, instead of being backed into houses, would remain on the streets until the drains have time to remove it.

To determine a safe basis for fixing the capacity of the drains, the record of rainfall made by the U. S. Signal Service in Chicago is used. The following summary is for 12 years from 1872 to 1883 inclusive. It gives

the average number of rainy days, and the average rainfall for each month, the number of days upon which the rainfall exceeded the limit given, and the number of showers exceeding one inch in magnitude :

Month.	Totals and averages from 1872 to 1883 included.						No. of showers exceeding 1 inch in magnitude.
	Average monthly rainfall for 12 years.	Average No. of Rainy days for each month.	No. of days of 24 hours each upon which the rainfall exceeded in the 12 years.				
			1 in.	2 in.	3 in.	4 in.	
January	1.87	12	3	......	......	......	1
February	2.36	11	4	......	......	......	3
March	2.79	14	7	......	......	......	6
April	3.64	13	13	......	......	......	14
May	4 05	12	11	3	......	......	9
June	4 36	13	13	1	......	......	13
July	3 90	11	10	3	2	1	10
August	2.72	10	9	1	......	......	8
September	3.00	10	12	2	1	......	11
October	3.86	12	13	1	......	......	12
November	2.89	13	6	3	2	......	6
December	1.96	13	5	......	......	......	5
	37.40	144	106	14	5	1	98

While there has been 1 rainy day in every $2\frac{1}{2}$ days, there was only 1 in 41 when the rainfall was as much as 1 inch in 24 hours, and but 1 in 313 when it amounted to 2 inches in 24 hours, and but 1 in 876 when it was as great as 3 inches in 24 hours, and but 1 in 12 years when the amount has equaled 4 inches in 24 hours. In only one shower has the rate of precipitation for the whole duration of the storm been $\frac{3}{4}$ of an inch per hour. There have been but two or three showers that the average rate has exceeded $\frac{1}{4}$ of an inch per hour. The heaviest rainfalls have invariably occurred during the summer and fall months. During December, January, February, March and April, the rainfall has never equaled 2 inches in 24 hours.

From the above and other considerations, it was decided to recommend that the mains be proportioned to carry $\frac{1}{12}$ of an inch, and the laterals $\frac{1}{3}$ of an inch rainfall per hour. The apparent difference in capacity between such a system as this, and one designed for $\frac{1}{2}$ an inch rainfall per hour, is 1 to 6; but owing to certain allowances which have been made in the formula generally used in proportioning the mains for large districts in a combined system of sewerage, the disparity is not nearly so great. Thus comparing with sizes determined by Kirkwood's and Bazalgett's formula for large districts and slight inclinations, such a system would have one-third of the capacity of the former and one-half of the capacity of the latter. Such a system will greatly reduce the cost of the drains and of the pumping machinery.

The sewerage systems which are to be distinct from the storm-water drains are to centre at the respective pumping works. In designing these systems the basis for proportioning the sewers is to be as follows :

Assuming that for each 25 feet of front there are 5 persons, and that the maximum rate of water used is 120 gallons per person in 24 hours, o five gallons per hour, then in a mile of street there will be about 10,000

gallons, or say 1,333 cubic feet of sewage per hour. In addition to this there will be some sub-soil water get into the sewers, and in times of rain some surface water will find entrance through open man-hole covers. If we assume this to be one-half of the sewage proper, we will have 2,000 cubic feet per hour per mile of street. As the land is generally subdivided in Hyde Park, there are 16 miles of streets upon which the frontage should be counted; hence on the basis assumed, sewers should be proportioned for 32,000 cubic feet per hour per square mile, or 50 cubic feet per acre.

When a sewerage system is to be carried out over a wide expanse of level territory, it is difficult to get self-cleansing grades for the sewers without going to a great depth at the lowest point of the system.

This difficulty is an unusually serious one in Hyde Park, where it is encountered in the main storm-water drains to a limited extent, but far more seriously in the sewerage. Below the sand, which extends over nearly all the central district, is a bed of drift clay of the character of that in which all tunnel work has been done in and about Chicago. It is proposed in order to cheapen the work, and to go low enough for self-cleansing grades, to build the main conduits for both storm-water drainage and sewerage, and a considerable part of the sewerage sub-main, by tunneling. To do this the grade of the storm-water conduits will have to be 25 feet below datum, and of the sewers, 32 feet below datum at the Grand Crossing pumping station, and perhaps somewhat deeper at the South Chicago station.

As the drainage and sewerage mains can usually be located on the same line, and as the one is six or seven feet higher than the other, it is possible to build them in the same excavation, one above the other. The cross sections given on the accompanying plan will convey a good idea of the form of construction proposed, when the two mains are built together. This can only be done with profit when it is desirable to build both mains at the same time. If, as will doubtless often be the case, it is necessary or desirable to build the sewerage mains earlier than the storm-water mains, the work can still be done in tunnel, by making some of them larger than the capacity required to carry the sewage.

The pumps for each class of work must be so placed that they can pump down to the bottom of the mains of the respective systems. To do this properly, it will be necessary to place the pump floor ten feet below datum.

We do not deem it necessary to provide a receiving reservoir for the storm-water drains, but intend that the storm-water pumps shall take the water direct from the mains. The mains leading to each station are to converge into one, which runs parallel with the building at an increased depth, from which the pumps can draw.

Neither for the sewerage mains do we think it advisable to provide a reservoir. For the sake of giving relief to the pumps and of dispensing with pumping at night, a reservoir of sufficient capacity would be extremely desirable. At the great depth, however, necessary in this case it would be quite expensive, though easily obtained, from an engineering standpoint. All that will be necessary is to build galleries by tunneling a little lower than the invert of the sewers. This can be carried on to any extent desired without occupying land.

If the main and sub-main sewers are built by tunneling, as they should be, they will be much larger than the mere requirements of flow through them. This surplus capacity can be used for the storage of the sewage in contingencies, and it will be cheaper than storage that can be obtained in any other way. The only serious objection that can be urged against it is a sanitary one. Though, as no houses will be connected directly with these deep sewers, this objection can be mainly overcome by trapping the lateral sewers where they connect with the sub-mains, and by their thorough ventilation independently of the laterals, together with ample provisions for flushing them.

When carried out to completion the total amount of storm water to be pumped by each station will equal 40,000 cubic feet per minute. When but little water is flowing and the mains are nearly empty—which will ordinarily be the case at the beginning of a storm—the lift for storm water will be about twenty-five feet, as a maximum.

In storms that tax the capacity of the pumps and mains, it is expected that the water will rise at the pumping stations to within eight feet of datum—at which stage the drains are to have a capacity of one-twelfth of an inch per hour—and as it will be seldom that the water will have to be lifted to a greater height than four feet above datum, it is safe to take the lift during heavy storms at about twelve feet.

The annual work of the pumps is estimated as follows:

The average annual rainfall for twelve years has been thirty-seven and one-half inches. If we assume that in the course of a year one-third of this escapes by evaporation, there will remain twenty-five inches to be carried off by the drains. This, on the whole area of twenty-two and one-fourth square miles, equals 1,292,000,000 of cubic feet to be pumped to the average height for the year, say, of fifteen feet, which is equivalent to the performance of about 37,000,000 of horse-power.

The class of pumps best adapted to this work is doubtless some form of rotary pump, with direct-acting engines, coupled in pairs. The centrifugal pump being best adapted to heavy work under low head, and a positive-acting rotary pump for light work under higher head. Owing to the irregularity in the amount of water to be pumped, the pumps should not be of uniform size.

The amount of sewage to be pumped will generally about equal the water supplied to the population within the district, though at times it will be likely to be much greater than that amount.

The lift will depend upon the distance to, and the elevation of, the land selected for sewage disposal, and upon the relative size of the main through which it is forced to its destination, as well as upon the depth of the sewers at the pumping works.

Direct-acting, compound, condensing, piston or plunger pumps, are recommended for sewage pumping.

At the present time the greater part of the Central district is unoccupied, so that the thing most needed is storm-water drainage of such a character as will render the lands tillable and fit for occupancy. Except in the more thickly settled communities sewerage will not be needed immediately. Surface drainage is proposed by means of open ditches for these unoccupied lands.

To excavate the main drainage ditch from State street to the Calumet Lake, to open up other main ditches, to construct dykes and flood-gates, to build the two pumping stations and furnish machinery for each, with a capacity of 10,000 cubic feet per minute, is estimated to cost $260,500. After this is done, it will only be necessary to increase the pumping plant as the permanent system of drains may be carried out. While the lands remain unoccupied, it is estimated that the cost of running the pumping plants will amount to $16,770 per annum, which is equal to $1.18 per acre per annum.

The conclusions regarding sewage disposal are, that all methods in vogue where water-carriage sewage is to be dealt with will come under one or another of the following heads:

1st. Chemical and mechanical precipitation processes.

2d. Discharge into streams or bodies of water.

3d. Land purification.

The processes coming under the first head are numerous, and have had repeated trials in Europe, but without any of them securing permanent recognition as being suitable for general application, when cost and the purity of the effluent water is considered. Such methods are not now being supplied in new cases to any great extent, and they have few, if any, advocates of importance.

The discharge of sewage into streams or bodies of water, is the method of disposal almost universally practiced in the early history of the sewerage of European and American cities, the nearest water-course being put to this use without hesitation, a brook or a sluggish river being used as freely as the ocean. As cities have increased in size the nuisance thus created has, in a majority of instances, become intolerable. Numerous instances of European and American cities are given in exemplification of this proposition, such as Boston, Buffalo, Philadelphia, Cleveland, Toronto, Providence. Milwaukee, Chicago, and many other cities of less importance which have had experience in the polluting power of sewage, and are now endeavoring to find deliverance from themselves, or have paid dearly for the deliverance. There has as yet been no case of a city of the size of Chicago emptying all its sewage into a body of water similar to Lake Michigan, from which it draws its water supply. The greater portion of the Chicago sewage has, since the deepening of the Illinois and Michigan Canal, been taken down the canal. And with the operation of the Bridgeport pumping works, a still greater portion, probably 90 per cent. will escape in that direction. Hence sewage discharge into Lake Michigan or into the Calumet Lake or river is condemned. Such a course would so pollute the Calumet Lake and river as to render them intolerable. Large quantities of sewage, if discharged into Lake Michigan far enough from shore, would probably have no worse effect than to render the water within a certain compass unfit for potable purposes, and such a course would not be objectionable except for this reason, provided always that the discharge took place in deep water, and far enough away to prevent pollution of the shore.

In the organic world there is a never-ending process of building up and tearing down going on; the inorganic elements of the earth being built into organisms which live for a time and die. Under proper conditions,

after death, decomposition—the resolving of the organized tissues into their original inorganic elements, or into some stable compound of a simpler nature—sets in, and continues until all the matter has lost its organized form. In their healthy state the organized tissues may be a wholesome food, but in some of the stages of decomposition they may be extremely unwholesome. Then, there is danger of disease germs, of certain kinds, being conveyed through the medium of drinking water polluted with the excreta of diseased persons. Though scientific men are not a unit in the belief that disease is likely to be imparted by taking living germs into the stomach, there is a vast accumulation of facts that point to the reality of the danger. Though the engineer, as such, may have nothing to do with the investigation of the causes of diseases, and the manner of their spread and propagation, it is his duty to avail himself of the deductions of specialists in this branch of science, and to be guided by their conclusions in cases of this kind. He should also give heed to such simple facts as come within the range of common observation. To this class outbreaks of sickness caused by the pollution of Lake Michigan by Chicago sewage belongs. In the spring of 1876 a great flood swept the contents of the Chicago River and its branches into the lake, causing a perceptible contamination of the water supply. According to the testimony of observant physicians this was followed by an outbreak of bowel complaint, particularly among children. Again in January and February, 1880, a period of heavy rains was followed by a similar result. At other times, in a less degree, the same injurious effects have been experienced, until it has come to be a well recognized fact that floods produce a marked pollution of the water supplied to the city.

The history of land purification of sewage, both by sewage farming—when the crop derived is the main object—and by what is termed "intermittent downward filtration"—when to the amount of sewage purified is attached the greater importance—is briefly reviewed.

The success attained in land purification of sewage, interests us only in its sanitary and financial aspects. A just judgment of these results will give the greater prominence to the former. The great error made by many of the early advocates of this method of sewage disposal was in emphasizing too strongly the financial part of the question. Not content with a sanitary measure, scarcely self-sustaining in some cases, and but slightly more in others, they made fanciful estimates of profits to be derived from sewage farming, which have not generally been realized. In a sanitary way, experience teaches that land purification of sewage is successful on the whole. The only cases where it has fallen short are those where the land is not properly prepared by artificial or natural means for the reception of the sewage, or where the method of distributing the sewage is defective, or where gross carelessness has existed in the management. The financial results have been very diverse, Though the extravagant expectations of its early advocates have not been fully realized, a good degree of success has been attained. Indeed it may be said that, in the light of experience, as much has been realized as could reasonably have been anticipated.

In deciding upon the character of the sewerage system to be adopted, our aim has been to avoid all really unsanitary measures. On this ground

the exclusion of sewage from Lake Michigan, Lake Calumet and the Calumet River, is urged with all the force of a positive conviction, that to pollute their waters will be a mistake that should not be condoned on the plea of ignorance, economy, or of necessity. Such a plea should receive no more consideration at the present day, than would the allegation that we ought to adopt the ancient habit of forming middens at the entrances to our dwellings, because it is cheaper than modern sewerage. To avoid the contamination of these bodies of water, it is necessary to keep separate the sewage, and storm water; hence a double system is recommended, with land purification of the sewage.

It is impossible to give with assurance the ultimate cost of carrying out to completion the system of drainage and sewerage proposed, for the reason that there are too many uncertain factors entering into the problem, such as the effect of the quicksand and water which will be encountered, and the manner of growth and expansion of the village. This difficulty, however, attaches to any plan which could be proposed. Nor is it particularly desirable that the total cost should be given now, provided the relative cost of this, and some alternative system, which would be practicable under ordinary conditions, is known; and provided the village can have the assurance that no unreasonable or extraordinary expense is to be blindly incurred. Such an assurance can best be given by comparing the probable cost of the double system proposed with the ordinary combined system of sewerage as in use in cities similarly situated.

In Hyde Park, as has been seen, there are generally, though not always, twenty-four miles of streets for each square mile of territory—sixteen miles in a north and south direction, and eight miles in an east and west direction. To cover this with a combined system of sewerage, similar to the one carried out in Chicago, there would be sewers on every street running north and south, and on every other street running east and west, or twenty miles of sewers to the square mile. For storm-water drains, as proposed by us, there will be eight miles east and west, and one mile north and south, or nine miles per square mile. For the sewerage system there will be sixteen and one-half miles north and south, and about one and one-half miles east and west, or eighteen miles in all. There is a great variation in the cost of sewerage for different cities, as will be seen from the following statement:

In the beginning of 1881 the average cost of a combined system of sewers in Brooklyn had amounted to $25,600 per mile. In Providence, R. I., a similar system up to the same time had cost $34,550 per mile. In St. Louis, up to the first of the present year (1884) the cost had been $30,146 per mile, and in Kansas City $20,727 per mile. In Chicago, on January 1, 1883, there were three hundred and eighty and nine-tenths miles of sewers that had cost an average of $15,458.42 per mile. A separate system of sewerage in Memphis, Tenn., to the first of 1884, had cost $6,875 per mile; in Leavenworth, Kan., about $10,000, and in Keene, N. H., about $7,000 per mile. At Pullman, the separate system has cost something less than $10,000 per mile. This, however, includes the more expensive part of the work. When carried out to completion, it will probably be reduced to about $8,000 per mile.

Were it possible to build a combined system of sewerage in Hyde Park without pumping, the system would still be more costly than the Chicago system, owing to more difficult construction and to the territory lying more remote from the outlets. It is fair to presume that its cost would be twenty per cent. greater than for Chicago, or say $18,500 per mile. This would make the cost per square mile for a combined system $370,000.

The system of storm-water drains proposed will cost considerably less per mile than an ordinary combined system, owing to the smaller size and less depth of the drains. We estimate the difference in cost at twenty-five per cent., or say $14,000 per mile for storm-water drains. The sewerage system will be likely to be somewhat more expensive than the Pullman system, owing to the sandy ground and greater size; this we place at $11,000 per mile. The cost of the drainage and sewerage of a square mile of territory, on the double systems proposed, is as follows:

Nine miles of storm-water drains, at $14,000	$126,000
Eighteen miles of sewers, at $11,000	198,000
Or a total of	$324,000

as against $370,000 by the combined system, a difference of $46,000 per square mile in favor of the double system, which on twenty-two and one-fourth square miles amounts to $1,023,500, which will go a long way toward building the two pumping stations, with machinery, and the main outlet ditch. We therefore feel fully warranted in saying that the double system proposed by us, when complete, including pumping stations complete, will not cost materially more than a single combined system having a gravity discharge, were it possible to construct such system, and that it will cost much less than the combined system has cost in many of the large cities of the country.

Some of you will remember a paper read before our society eight years ago by Mr. Frederick Wilcox Clarke—a former member—entitled the Artificial Drainage of the Calumet Marshes. Mr. Clarke's paper dealt with the same district substantially that we have been considering. Mr. Clarke was then the engineer in charge of the proposed work of draining this district. At that time the Calumet region had not assumed the importance that it now possesses, and the only thing contemplated was a system which should render these lands suitable for agricultural purposes. Messrs. E. S. Chesbrough, Wm. Sooy Smith and W. H. Clarke were consulted with reference to the plan then proposed, the outcome of which was a report from them to the Board of Trustees recommending the main features of the plan described by Mr. Clarke, which included the establishment of one pumping station at about the point where the South Chicago station is shown on the map, with centrifugal pumps of a capacity of 6,600 cubic feet per minute. This would be sufficient to remove $\frac{1}{5}$ of an inch rainfall in twenty-four hours; the surface ditches at the same time to have storage capacity for $\frac{4}{5}$ of an inch rainfall, making one inch stored and pumped in 24 hours.

The striking peculiarity of the current controversy, relative to the comparative economy and sanitary merits of the separate and the combined systems of sewerage, is the large amount of irrelevant testimony produced,

and the erroneous arguments advanced in support of this or that proposition. The more thoroughly one becomes acquainted with the design and construction of sewerage under the ever-varying meteorological, geological and topographical conditions of different parts of the country, the less reliance will he place upon comparisons between systems of different kinds, or even between those of the same kind, unless he can have an assurance that the comparisons have been made upon a reliable basis. To do this, not only must the unknown quantities due to physical differences be eliminated, but the personal factor must be known. For in any equation expressing equality or inequality between two systems, there is an important personal factor which usually has an unknown and variable value. In the matter of cost, of what avail is it to compare a combined system of sewerage, like the one being carried out in Washington by the Engineer Department of the District of Columbia, designed for two inches of rainfall per hour, all pipe sewers being bedded in concrete. with another one designed for ¼ of an inch rainfall per hour, the pipe sewers being bedded in the ground ; or to compare the Memphis separate system of sewerage, laid at an average depth of six feet, with one whose least depth is six feet and greatest sixteen ? To say that a combined system of sewerage in Kansas City has cost $20,727 per mile, one in St. Louis $30,146 per mile, and so on through the whole list, while the Memphis separate system has cost but $6.875 per mile, and that separate systems elsewhere have cost from $7,000 to $10,000 per mile, gives no adequate idea of what system will be found cheapest to adopt for a particular place when all the conditions of present and prospective necessity of storm-water drainage shall have been considered.

I believe I am safe in asserting that, taking the various cities and towns of the country promiscuously, it will be found that in 75 per cent. of them the instigating cause of their moving at all in the matter of sewerage is the pressure to secure storm-water drainage, and that in not to exceed 25 per cent. of the cases is the desire for sewerage more than of secondary importance. Hence the futility of comparing figures that on one side include this storm-water drainage, with others that wholly ignore it.

What is to be learned in a sanitary way by comparing a badly designed, poorly constructed, and ill maintained combined system of sewerage with a separate system made as perfect as modern art will allow ?

What does it prove to say that the death rate of Memphis, with its separate system of sewerage, was for 1881, 42 1 per 1,000 ; for 1883. 30 9 per 1,000. and for 1884. 37.1 per 1,000 of population.* and that the death rate was only 21 per 1.000 in St. Louis with its combined system during the same time? Or that Pullman, with a double system, one for sewage and one for storm water, has had a death rate of only 7 per 1,000 since it was founded? Is this difference between Pullman and Memphis due to a system of storm-water drains which the one has, and the other has not? Clearly not, any one must admit. But to maintain that it is, would be just as logical as much of the reasoning indulged in to prove the superiority of one system over another. Baltimore has a death rate as low

* See Kansas City Sewerage and Separate versus the Combined System, in Journal of the Association of Engineering Societies, Vol. III., pp. 74, 85 and 189.

as any city of its size in the country. Can it be due to the general use of privy vaults, and almost an entire lack of sewerage? Few sanitary engineers would be bold enough to answer this in the affirmative.

Thus far the irrelevant in the controversy. Is there, then, nothing to aid one in forming a correct judgment upon this subject? I believe there is, if it is only approached in a scientific manner, with a clear understanding of terms, and by recognizing fully what is included in the word sewerage when applied in the popular sense.

If we would avoid confusion, we should remember that, strictly speaking, drainage is the removal of storm water from the surface of the ground, and from the subsoil: and that sewerage is the removal of waste substances from dwellings, manufactories, and other buildings by means of water flowing in underground conduits. And further, that when these two purposes are wholly accomplished by one system of conduits we have the full combined system of sewerage, and that when it is done by two systems of conduits, one for sewage, and one for storm water, we have the double system, though in one sense it might appropriately be called the separate system.

When there is but one system of conduits, used exclusively for sewage we have the separate system in the cheap and popular conception of the term.

In addition to the above distinctions, we have further differences, growing out of the completeness of the combination, or of the extent to which two systems of conduits may be carried out. Thus, only water from roofs may be admitted with sewage, throughout the whole system: or water from roofs may be admitted only to the lateral sewers, while that from ground surfaces as well is taken into the mains; in either of which cases we have, strictly speaking, a partially combined system; though when only water from roofs is admitted it is usually, but, as it seems to me, incorrectly, spoken of as a separate system.

There may also be one system of conduits for sewage removal, and a partial system for storm water, in which case we would have a double system in part. Or roof water only may be admitted with the sewage, while a partial system of storm-water conduits are used for the surface drainage of the ground.

Again, there are often circumstances under which a combined, or a partially combined, system may be appropriately used, with storm-water overflows into a natural drainage channel, into which it would not do to discharge the constant flow of sewage. This may be called an intercepting system.

With such a variety of combination and separation—examples of all of which are to be seen in this country—the futility of the comparisons of the separate and the combined systems which are often indulged in, becomes still more apparent than may have appeared at first glance.

So far as I am aware, there is no statistical evidence to show that one system of sewerage is to be preferred to another on sanitary grounds. In the absence of such statistics, our conclusions must be drawn from certain well-known laws, from partially or wholly unverified hypotheses, from personal experiences as colored by our individuality, and sometimes, it must be confessed, from self-interest.

As it is the combined system alone that is seriously impeached on such grounds, the controversy begins with it, and will end only when its sanitary, or unsanitary, qualities shall have been thoroughly established. I believe that the following statement contains all the charges of any moment that have ever been brought against this system:

1st. The interior surfaces of the sewers being greater than in a separate system, and being exposed to fluctuations of storm water, an accumulation of sewage matter takes place thereon, which, after the water has seceded, decomposes.

2d. The cross-section being greater, ventilation is less perfect than it would be in a smaller sewer.

3d. Owing to the greater cross-section than is needed for the dry-weather flow of sewage, the sewage spreads over more surface; that is, it has a less hydraulic mean depth, and hence less scouring action than it would have in a more confined channel.

4th. Dead ends of the sewers being larger, they cannot be as readily flushed as in a separate system.

5th. The inclinations for a combined system being sometimes calculated on the basis of the sewers carrying $\frac{1}{3}$ or $\frac{1}{2}$ their capacity, while the dry-weather flow may be only $\frac{1}{10}$ to $\frac{1}{20}$ of their capacity, the velocity during their minimum flow is insufficient.

6th. Street detritus and rubbish admitted through street inlets form deposits in the sewers.

To these objections the following answers may be made:

1st. It requires but a limited acquaintance with the innoxious character of the slime that is to be found on the sides of a sewer above the water line to break the force of this objection. Besides, it would apply with almost equal force to a system of exclusively storm-water drains.

2d. How ventilation can be more thorough in a small channel than in a large one it is difficult to conceive, if the openings for ventilation are anywhere nearly proportioned to the capacity of the sewers. Indeed, the larger sewer will do with less openings, and still be ventilated as well as the smaller one, because of the freer circulation, and because the proportion of sewage to the area of the sewer is less; and hence, everything else being equal, less gas is given off in proportion to its area.

3d. A cross-section for main sewers can be and is frequently used that will give as great a hydraulic mean depth for the dry-weather flow as a small pipe can give. When sewers are designed for an ordinary amount of storm water, the common egg shape, with the invert made of suitable material, will accomplish this end. When, as at Washington, the storm water provided for is excessive, the section adopted by the Engineer Department, which is the usual egg shape, with a half-pipe invert, fills every requirement.

Owing to the fact that the smallest pipe used in a separate system—six inches—is much in excess of the requirements of flow, while in a combined system this is not the case to the same extent, the disparity of size in lateral sewers is not so great as in the mains. Usually a full combined system would require a 12-inch or a 10-inch pipe where there would be a 6-inch in a separate system. And a system receiving only roof water would require a 9-inch or an 8-inch pipe where there would be a 6-inch in the separate system.

The following table gives the velocity in feet per second, the maximum depth in inches, and the hydraulic mean depth in inches, for circular pipe sewers of various sizes, each having an inclination of $\frac{6}{10}$ per 100 feet when each sewer is carrying about $\frac{1}{4}$ of a cubic foot per second, which is the amount discharged by a 6-inch pipe having the inclination given, when running half full:

Size.	Velocity.	Maximum depth.	Hydraulic mean depth.
6″	2 70	3.0	1.50
8″	2.67	2.6	1.48
9″	2.66	2.5	1.47
10″	2.63	2.4	1.44
12″	2.55	2.2	1.39
15″	2 50	2.1	1.32
18″	2.46	2.0	1.24

It is thus seen that, in passing from a 6-inch pipe to a 12-inch one, the velocity is decreased $5\frac{1}{2}$ per cent., the maximum depth $26\frac{2}{3}$ per cent., and the hydraulic mean depth $7\frac{1}{3}$ per cent. For other inclinations the percentages will run about the same, which certainly does not indicate as great an advantage in the small pipes as one would be led to expect from the claims put forth for them.

4th. If a pipe 6 inches in diameter can be flushed with a given quantity of water, either automatically or otherwise, a pipe of a larger diameter can be flushed in the same way with a proportionately larger amount of water and larger-sized flushing apparatus.

5th. It is a sufficient answer to this objection to say, that if in a given case suitable inclinations can be obtained for a separate system of sewerage, exactly the same inclinations can be had for a combined system.

6th. This objection must, under conditions of slight inclinations, be admitted to be of considerable weight, though just how much weight it should have it is difficult to determine. With inclinations that give velocities sufficient to prevent the deposit of road detritus, the objection does not hold, nor does it have application where only water from roofs is admitted.

As an offset to the evil of deposit in a combined system of sewerage, it is legitimate to oppose the advantage which it has—particularly on the pipe sewers—of being thoroughly flushed by the sudden admission of water from roofs during every considerable rain. One may readily be a full offset to the other under like conditions of design and construction.

It is, therefore, my serious conviction that no sanitary defects have been pointed out in the combined system of sewerage, that are not neutralized by corresponding advantages, and that it should not be excluded from use in those places where it is the cheapest and most convenient thing to adopt.

The magnitude of the acknowledged defects of the combined system, no one knows with certainty. Indeed, being largely subjective, and hence dependent upon the state of mind of the individual, it may take on any proportions within the reach of the imagination; just as the question of the propriety of using water-closets, baths, wash-bowls, etc., in our dwellings is wholly dependent upon individuality. There are persons who are, in the main, well qualified to give advice on such subjects who will condemn the use of such fixtures; while some of us know, from actual experience and close observation, that such condemnation is


THE
SEPARATE VERSUS COMBINED
SYSTEM OF SEWERAGE
as exemplified in
the
DRAINAGE OF HYDE PARK
DRAINAGE MAP
SCALE
1 MILE
LAKE MICHIGAN
WOLF LAKE
HYDE LAKE
LAKE CALUMET
STONY ISLAND
WASHINGTON PARK
WASHINGTON PARK CLUB.
CENTRAL DISTRICT
22½ SQUARE MILES.
35 AV. ELEVATION 6.0 FT.
MAIN DRAINAGE DITCH
GRAND CROSSING
SOUTH CHICAGO
HYDE PARK LAKE DISTRICT
PULLMAN DISTRICT
PULLMAN
KENSINGTON
HEGEWISCH
SEWAGE FARM

uncalled for, and that it is perfectly safe to use them when properly and honestly put in place.

If these conclusions are correct, we may use with propriety any one of the systems, or combination of systems, where the conditions are such as to make it applicable. In the sewerage of any place we have then only to consider its needs ; to what extent, if any, the storm water must be carried in underground conduits ; where, and how it can be discharged ? what can be done with the sewage consistent with the conditions of the case, and our best sanitary knowledge ; and the mechanical means, if any, that are to be employed in its disposal. These things being known, and their conditions complied with, the only thing to consider in the choice of a system is cost. This will lead to a wide variation of practice.

Thus, supposing in a given case, sewage and storm-water can be disposed of together, by gravity discharge in the nearest place of outfall, then if it is necessary to resort to underground carriage for storm water, the combined system, or a partially combined system, will be the best and cheapest to adopt. The only exception to this rule that can possibly arise is where the territory, as in Hyde Park, is very flat and extended. In such a case, as shown by the estimate of cost of the Hyde Park drainage, a slight saving may, in some places, be made by the use of a restricted system for storm water, though it would be accomplished at the sacrifice of other advantages afforded only by a combined system of sewerage, such as the possibility of every house having a single connection with the sewers through which both storm water from roofs, as well as sewage, can be carried, and the possibility of a prompt removal of surface water from the streets under all conditions. Simplicity would also be sacrificed by the double system.

If, however, owing to the manner of sewage disposal to be adopted, the sewage must be pumped, or used in irrigation, or treated chemically, or carried an extraordinary distance to the out-fall, then it will generally be the best and cheapest to use the separate system, with or without a partial, or a complete system of storm-water conduits.

The exception to this rule is found when a suitable place near at hand can be had for the overflow of surplus storm water, so that an intercepting system can be adopted.

The statement that a combined system of sewerage is cheaper than a separate system, under the limitations given, is based upon the well-known fact that other things remaining the same, the cost of sewers of different sizes increases in a ratio but little greater than the increase in their diameters, while their capacity increases in a much greater ratio than the *squares* of their diameters; so that it may be said to be an axiom, that I believe can never be successfully gainsaid, that with the conditions of ordinary practice, if a given amount of sewage, and a given amount of storm water, are to be conducted along a particular street through underground channels, it can be done cheaper in one channel than in two. At any rate, this axiom does not seem to be invalidated by the criticism of Mr. Gray's report on "A Sewerage System for the City of Providence," made by Col. Waring in the *American Architect* of January 24, where he says :

"It is not easy to conceive of conditions requiring the sewers for storm water

removed, and the removal of house drainage to be coextensive; consequently the suggestion that 'the cost of the entire combination will usually exceed the cost of a combined system,' cannot be accepted as a valid argument. There is no instance recorded of the greater cost of the sewerage of a city by the separate system than by the combined system, and it is doubtful whether one-half of the cost has ever been reached."

If the latter part of this statement of Col. Waring's were true in fact, it would hardly prove what he desires that it should, for it can be met by the further fact that no city in this country, used to modern city improvements, and unfavorably situated for natural drainage, has ever adopted the separate system without making ample and expensive provisions for the underground removal of storm water. Nor is it likely that such a case ever will occur, unless it may be in the way of an experiment that will not last when put to the test.

Col. Waring, however, is mistaken in his facts. The double system at Pullman consists of a sewerage system, and another system, co-extensive with it, used exclusively for storm-water drainage. The system for storm-water drainage is as complete in all essentials, and has cost as much, as a combined system would have cost draining into the same outfall; so that here, at least, the total cost of drainage and sewerage is greater than the cost of a combined system, by the amount of the whole cost of the sewerage proper.

At the risk of indulging in apparent repetition, I desire to say that neither Col. Waring nor any other advocate of the separate system as cheaper at all times and in all places, has ever advanced an argument tending to alter the conclusion, that a given quantity of sewage and a given quantity of storm water can be carried at less expense in one conduit than in two, and that all the arguments used for the all-time and all-place cheapness of this system start with the fallacy of either ignoring storm-water drainage entirely, insisting that it can be accomplished through special means at a cost next to nothing, or, if the combined system is suggested, persisting that all storm water must be taken into the sewers, whether or no; allowing none of the makeshifts with this system that are extolled as of wonderful virtue when yoked to the separate system. Until it can be shown that a makeshift, good with one system, is not good with another, and that if it is possible and convenient to dispense with the underground carriage of storm water in one part of a city, when a distinctively separate system is in use, it would *not* be possible and convenient to do the same thing, for the same part of the same city, if a partially combined system was in use; or that the advantage of so doing would not accrue to one system as largely as to the other, for that particular part of the city. It certainly seems that the financial arguments for the separate system should be dropped except in special cases, and entire attention given to those of a sanitary character, in which differences of opinion can exist with less violence to our logical faculties.

Whether or not I have succeeded in making clear to you the futility of discussing the relative economy of the combined, and separate systems, without regard to all the attending circumstances; whether or not the erroneousness of many of the arguments used to prove this or that

proposition is apparent to you, I have at least succeeded—perhaps at your expense—in clearing up some doubts touching the subjects, that were in my own mind previous to studying the Hyde Park problem.

VENTILATION OF STABLES.

By Augustine W. Wright, Member of the Western Society of Engineers.

[Read February 3, 1885.]

About six years ago, it became my duty to prepare plans for a stable to contain two hundred horses engaged in the street railway service of this city. These horses spend about twenty of the twenty-four hours per diem in the stable. The horse is a sensitive animal, and his diseases closely resemble many of those under which his master, man, suffers. I enlarged upon this fact in a paper that I had the honor to read before you, entitled "Stable Construction," in July, 1884, and I trust you were so convinced of these facts, that it is not now necessary to say more upon that subject. Realizing the paramount importance of ventilation, I desired to ascertain the proper amount of air to provide for each animal. I turned to my engineering library, and consulted book after book, in vain, for the desired information. I then went to one of the prominent engineers of this city, and asked him "How much air does a horse breathe per minute?"

He said: "Well, I don't happen to remember just now, but about the same amount as a man." I thought it must be greater, and turned to the Public Library, where I examined every book that I thought might contain the information, but could not find it. Not disheartened at my failure, I looked through half a dozen other leading works upon the horse, but could not secure the coveted information, although Stonehenge contained the following: "By common consent, it is allowed that no stable, divided into stalls, should give to each horse less than 800 or 1,000 cubic feet;" and the *Civil Engineers and Architects' Journal*, 1841, page 103: "The committee of the Academy of Paris, to whom the question, What is the quantity of air necessary for the healthful respiraation of the horse? was referred by the Minister of War, reported that in a building where the air is properly renewed, and that result is effected by a skillful and efficient system of ventilation, a horse can never suffer so long as he has from 25 to 30 cubic meters of air," 883 to 1,060 cubic feet. These statements did not solve the problem. I had arranged already to give each horse 1,216 cubic feet of space, but I desired to know *how much air per minute* he must have. I now turned to the medical profession, and to a well-known doctor propounded the question: "How much air does a horse breathe per minute?" He said: "He breathes—he breathes (hesitating)—well, I don't remember just now." I asked in vain four other physicians, and veterinary surgeons. All *started* to answer the question, hesitated, and finally said they did not remember, but would look it up. This they did in vain. One said he had a friend, a physician, in the country, who was greatly interested in the horse, and no doubt *he* would know; but he could not answer, and I was perforce compelled to assume a certain amount and made my ventilators 6′ × 6′ on plan, tapering to

$4' \times 4'$, and $20'$ height, allowing one such for each forty horses. Assuming that air expands $\frac{1}{490}$ of its volume per degree Fahrenheit, and that it is winter weather, the interior of the stable being 15 degrees warmer than the exterior air—for in my opinion the horse enjoys better health if the stable temperature varies only 10 to 20 degrees from the exterior air than he does in a hot stable—the air inside the stable would lose in weight $20 \times \frac{15}{490} = .612$ foot. That is, it would be lighter than the outside air by the weight of a column of air .612 foot high. The velocity with which the outside column would try to get in at the base of this shaft would be governed by the same law as that of a body falling through the space of this excess of height. The formula for this velocity is $V = \sqrt{2\,g\,h}$. g representing the force of gravity, here 32 about, and h the height or space through which the fall is made; substituting, we have $V = 8\sqrt{0.612} = 6\ 26$ cubic feet per second; but we must deduct from this amount the loss by friction of the air against the sides of one ventilator. Being a straight box with smooth sides, this loss will probably not exceed 0.3 of 6.26 cubic feet, say 1.90 cubic feet. Deducting this amount from the former leaves 4.36 cubic feet per second passing through each ventilator; multiplying by 3,600, the number of seconds in one hour, and dividing by 40, the number of horses supplied by the said ventilator, $\frac{4.36 \times 3{,}600}{40} = 392.4$ cubic feet per hour per horse, as supplied under the forgoing conditions. In summer the doors and windows are open; and as most of my stables have light and air from four sides, through many openings, there is no trouble about ventilation at that time of year. I located my gas burners that light the stable under the said ventilators. The part they perform, assisting in the ventilation, is important. There are two four-feet burners under each ventilator. The quantity of heat evolved by the combustion of a cubic foot of ordinary illuminating gas is estimated at 700 heat units. The two burners would therefore evolve $2 \times 4 \times 700 = 5{,}600$ heat units per hour, or 93.3 per minute. The specific heat of air is 0.238 nearly. A cubic foot of air at 45° weighs 552 grains $\frac{552}{7000} = .0789$ lb., so that to ascertain how many cubic feet of air at 45° would be heated 1° by burning two four-feet burners per hour we have $\frac{93.33}{.0789 \times 0.238} = 49.701$ cubic feet, or 15.696 cubic feet, the amount passing through as per above estimate, heated 3.1°. Air expanding $\frac{1}{490}$ for each 1° of temperature, we see here additional power to carry off the impure air. These figures apply to the ventilator provided to carry off the impure air. Provision is made to admit fresh air through flues beneath the floor, extending clear across the stable, with an exterior opening at each end, covered with iron grates, to exclude rats, etc. Its cover is perforated, so that the air is broken up and admitted without drafts. The mangers on each side are boarded up 44 inches high, affording additional protection to the horse against drafts. The ventilator above the roof was first built with slats on its four sides, like ordinary blinds, moved by ropes extend-

ing to the first floor to regulate the amount of opening ; but we found it impossible to prevent *downward* drafts, chilling the horses. I then changed the construction ; took out the slats, and put in a slide with an angle board inclined at 45° on the four sides. The wind is thereby deflected upward. These slides are moved by ropes extending to the ground floor, and we now have no trouble from a current in the wrong direction. I would also state that I built numerous air flues in the brick walls at first, but had to stop them up, as the current passed through in the wrong direction. Instead of going out, cold air came down, and blowing upon the adjacent horses, chilled them.

Some months since the Boston *Journal of Chemistry* opened its columns for "Questions and Answers" to matters of general interest. Recognizing the eminent ability of Dr. Nichols, and believing that amid its numerous readers were many among the owners of the fourteen millions of horses possessed by this country, I propounded my so often asked question, "How much air does a horse breathe per minute?" It was not answered until the January number of the present year contained an editorial entitled "Ventilation of Stables," from which I quote : "According to authorities on ventilation, a man makes twenty inspirations of air per minute, each inspiration being of a volume equal to 40 cubic inches ; so that he requires 800 cubic inches per minute of fresh air to supply him with the necessary health-giving pabulum for his lungs. Each expiration unfits for breathing twice the bulk of fresh air ; that is, the 800 cubic inches expired per minute contaminate 1,600 cubic inches of fresh air, or nearly a cubic foot. Hence, in round numbers, a man requires a cubic foot of fresh air per minute, or 60 cubic feet per hour. * * * A horse or cow is said to have six times the breathing capacity of a man ; so that it will require 360 cubic feet per hour.

These figures agree quite closely with the amount I furnish each horse, as above stated, 392.4 cubic feet.

According to Pettenkoffer, an average pair of human lungs exhale about 15 cubic feet of air per hour, but authorities differ as to the proper amount of fresh air needed to keep the air in a fit state of purity. Peclet, calculating from the quantity of carbonic acid produced, says 5 cubic feet per minute per individual. Reid, adding for an amount to carry off all the contaminations resulting from human life, says 10 cubic feet. Arnott and Roscoe, 20 cubic feet per minute. Worthen allows 3 cubic feet per minute. Haswell states : "Each person requires from 3 to 4 cubic feet of air per minute." Box considers 3½ cubic feet per minute the minimum quantity necessary for cleanly and healthy persons. Philbreck thinks 50 cubic feet per minute the proper allowance, and Dr. Billings allowed 60 cubic feet per minute in the Johns Hopkins Hospital. Curtis, in his "Fresh Air in the House," states : "The mean number of respirations per minute in the case of 1,407 healthy males was found to be eighteen. * * * Then, if we take 230 cubic inches for the quantity of air necessary to a man of medium height for each breath and multiply this by the number of respirations per minute, we shall get something like the quantity required and which will give us 2.39 cubic feet as the fullest measure." Surgeon-Major F. de Chaumont, in a paper "On the Theory of Ventilation," estimates the cubic feet of air needed per

individual per hour, calculated from Angus Smith's estimate, that the amount of carbonic acid expired per hour per individual = 0.450, at from 530 to 2,460 cubic feet; by Dr. Parkes' formula, CO_2 = 0.600, from 700 to 3,280; by Pettenkofer's estimate, CO_2 = 0.705, from 825 to 3,850. He adopts Dr. Parkes' formula. Seven hundred cubic feet per hour per individual gives "a very close atmosphere; 3,280 cubic feet 'fresh,' no appreciably different sensation from the outer air." Gen. Morin, by actual experiment, found "different numbers of cubic meters of air per hour are required for different purposes. In hospitals for ordinary illnesses, 60 to 70 per hour, for each patient; the wounded require 100. Persons suffering from epidemics, 150. In prisons 50 are enough. In ordinary workshops, 60. In barracks—by day, 30; by night, from 40 to 50. In theatres, 40. In stables and stalls, 180 to 200." These figures, being in cubic meters, must be multiplied by 31.3156 to reduce them to cubic feet. Having done this, we find that from 939 cubic feet for the individual in the barracks to 4,697 cubic feet for the wounded are deemed necessary for each individual per hour by Gen. Morin, and from 5,637 to 6,263 cubic feet per hour for each horse. The English army regulations at the present time are said to allow to each horse a space of 1,605 cubic feet, 100 square feet of floor and 2,466 cubic feet of fresh air per hour. Philbreck, in his admirable work, "American Sanitary Engineering," states: "The standard of purity (of the air) must be a conventional and arbitrary one, fixed by experience and adapted to the class of occupants by whom a building is to be used." Applying these words to stable ventilation, permit me to affirm that experience demonstrates that *our* ventilation is sufficient. R. Atkins, Superintendent of the Horse Department North Chicago City Railway, reports: "The number of horses owned at the present time, 1,658; average number owned during 1884, 1,500; average number unfit for duty from *all* causes, 38½; but this includes a number of new horses (over 150) purchased fresh from the country to stock a new line, who suffered from distemper in being acclimated. Excluding them the average was 32, or about 2 per cent. Forty-five horses died during the past year—14 from accidental injuries, 10 from colic, 5 from lung fever, 4 from paralysis and 12 from 8 other diseases." Deducting the 14 from accidents and 10 from colic, leaves 21 deaths only that might have been remotely affected by ventilation, or 1.4 per cent. Surely this experience indicates ample ventilation. Having given so much time to this matter and believing it to be of general interest, I take great pleasure in submitting the same for your consideration.

THE ECCENTRICITIES OF THE TRANSIT OR THEODOLITE, AND THEIR INFLUENCES ON HORIZONTAL ANGLES.

BY JOHN EISENMANN, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read May 13, 1884.]

At the request of several members of the club, I have the pleasure of presenting to you the eccentricities of the transit or theodolite, and their influences on horizontal angles.

No piece of mechanism, no matter how delicately constructed, is as per-

fect as its theoretical counterpart. In spite of all the modern improvements, there still remain defects which in the future may be overcome by the makers. Even if they were overcome, it would require extremely delicate manipulation to keep them in perfect adjustment.

It is not my purpose to describe the mechanism of the transit or theodolite in use at the present day, nor their adjustments, as most of you are so familiar with them that further reference is unnecessary. Nor do I intend to discuss the accidental or unavoidable errors due to influences of the weather, light, temperature, personal equation, pointing at eccentric target, errors of phase, etc.; but will take up the eccentricity of the alidade and limb, and of the telescope, and the errors due to the inclination of the limb and the line of collimation.

The transit or transit-theodolite under discussion is the ordinary repeating one of every-day engineering use—10″, 20″ and 30″ instruments; the terms transit and theodolite being used synonymously.

When a theodolite is in good adjustment and set up for measuring angles, the line of collimation is perpendicular to the horizontal axis; the horizontal axis is perpendicular to the vertical axis, and the vertical axis vertical with the direction of a suspended plumb line. No matter how perfectly an instrument has been constructed, or how carefully its adjustments may have been made, it is never in an absolutely perfect condition. The coarser errors may have been disposed of, but the remaining, almost inappreciable ones, leave their influences upon all measurements, unless a programme of work be so arranged as to eliminate them. Fortunately this can be done; but before pointing out the methods of work, let us take up each source of error separately, and see just what its influence is.

In the following I have considered that the instrument is perfect, except in respect to the error that is being discussed; having found each independently, they will be compiled at the close.

The subjects will be taken up in the following order:

A. Eccentricity of the Alidade and Limb.

B. Eccentricity of the Telescope.

C. Inclination of the Limb.

D. Inclination of the Line of Collimation.

Those of you who are familiar with the angle measures and their adjustments, as given by Baurenfeind* or Jordan†, will recognize almost literal translations in the following theoretical discussions.

A.—General Relation of the Alidade and Limb.

The mechanical defects of a theodolite, in relation to its alidade and limb are:

1st. Eccentricity of centres. 2d. Eccentricity of verniers.

The eccentricity of the limb and alidade is readily shown when both verniers are read.

If the difference between the two is $180 \pm f$ and f remains constant, the centres C and D coincide and the verniers only are eccentric; but if f varies with each pointing, the centres C and D are eccentric and the

* Baurenfeind's Vermessungskunde, § 144, Vol. I.

† Jordan's Handbuch der Vermessungskunde, § 88, Vol. I.

zeros of the verniers may be in a straight line; or both the centres and verniers may be eccentric.

1st. *Eccentricity of Centres.*—Let Fig. 1 represent the circle of a theodolite, in which C = centre of graduated limb, D = centre of alidade, bearing the telescope and verniers.

There are two verniers, A and B, whose zeros are connected by the straight line ADB. Verniers are supposed to lie directly under the line of sight.

When the centres C and D coincide, there is no eccentricity. But, owing to mechanical difficulties, all instruments have their centres more or less eccentric. When C and D are the respective centres of the limb and alidade, $CD = e$ is the eccentricity, which, even in first-class instruments, is often 0.01 mm. to 0.02 mm. If we now proceed to read the angle $LDR = a$ with an eccentric instrument, the reading of

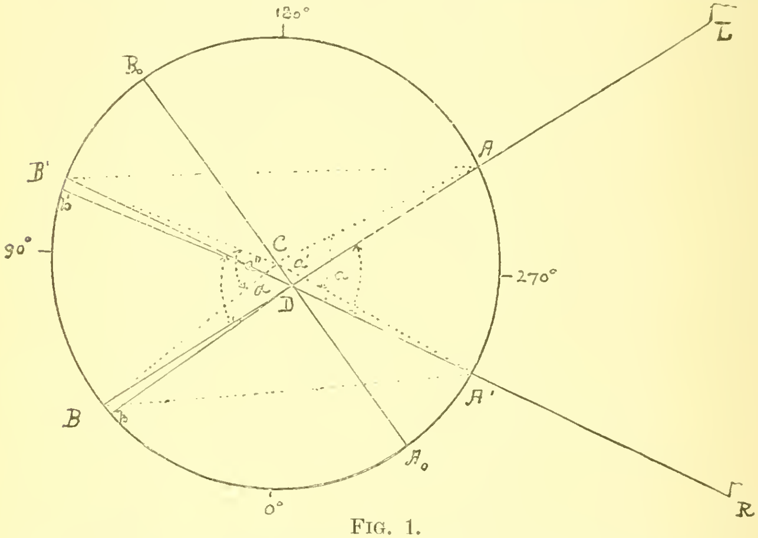


FIG. 1.

vernier A at A and A' will give the arc $A\,A'$, whose centre is at C, or the angle $ACA' = a'$.

a' may be either greater or less than a.

If, however, we read both verniers, assuming that ADB is a straight line, or that vernier $B = 180° + A$, we will obtain the values of the arcs AA' and BB', with centers at C, or the angles a' and a''; by taking the mean of a' and a'' we obtain value of a; *i. e.*,

$$a = \frac{a'+a''}{2}. \qquad (1)$$

This can be easily demonstrated from Fig. 1; for instance,

$$\angle\ ABA' = \frac{1}{2}\,a' \text{ and } \angle\ BA'B' = \frac{1}{2}\,a''$$

$$\angle\ ADA' = a = 180° - A'DB \text{ or } 180° - 180 + \frac{a'}{2} + \frac{a''}{2};$$

$$\therefore\ a = \frac{a'+a''}{2} \text{ which is the same as eq. (1).}$$

Thus, it will be seen that with two verniers diametrically opposite, by taking means of readings, the influence of eccentricity is eliminated. This is also true when the angle of inclination of vernier B to vernier A is very slight; *i. e.*, when $\angle BDb$ is very small and vernier $B = A + 180°$ approximately.

If the reading of angles is made with but *one* vernier, the eccentricity can be eliminated by transiting telescope and retaking the angles on the opposite side of the limb without disturbing the setting of the instrument. The means of the readings will then give the required angle.

If the eccentricity e and the angle which $e = CD$ makes with the 0°—180° line are known, the error made by measuring any angle with one vernier may be found from the following equation. Let us suppose that in pointing to the first station L, the vernier was set at 0°, then from Fig. 1, if

$e = CD$ = eccentricity of the alidade;
$r = CA = CB$ = radius of the limb;
$v = \angle ACD$ = angle of inclination of CD to CA or the 0°—180° line;
$u = \angle CAD$ = small angle subtended by CD at A;
$u' = \angle CA'D$ = " " " " CD " B;
a = true value of angle;
a' = measured value;
$a - a' = f$ = error made.

From inspection of the figure it will be seen that—

$$f = a - a' = u' - u. \tag{2}$$

Since CD is quite small, AD may, for the sake of approximating, be made equal r, and with the aid of the small triangles CAD and $CA'D$ we obtain the following equations:

$$\sin u' = \frac{e}{r} \sin v \text{ and } \sin u = \frac{e}{r} \sin (v - a') \tag{3}$$

u and u' both being very small angles, their sines expressed in terms of arc will make eq. (3) equal

$$u' = 206265'' \frac{e}{r} \sin v, \text{ and } u = 206265'' \frac{e}{r} \sin (v - a') \tag{4}$$

Substituting eq. (4) in eq. (2):

$$f = 206265 \frac{e}{r}\left[\sin v - \sin (v - a')\right]. \text{ which reduces to}$$

$$f = 206265 \frac{2e}{r}\left[\sin \frac{1}{2} a' \cos \left(v - \frac{1}{2} a'\right)\right] \tag{5}$$

which is the equation sought.

f becomes 0 when e or $\cos \left(v - \frac{1}{2} a'\right) = 0$. This is the case when $\left(v - \frac{1}{2} a'\right) = 90°$ or $270°$, *i. e.* when $a' = 2v - 180°$;

f becomes a maximum when $\cos \left(v - \frac{1}{2} a'\right) = \pm 1$, or when $v - \frac{1}{2} a' = 0°$ or $180°$ and $a' = 2v$.

If $v = 30°$, $a' = 60°$, $e = 0.0004$ in. and $r = 3.0$ in.

$f = 412530'' \times 0.00013 \times 0.5 = 26''.82$, or very nearly half a minute. This error, due to $e = 0.0004$ inches, shows conclusively that it is too large

to let go uneliminated, when an accuracy of more than the nearest minute is claimed for an angle; had e equaled 0.004 inches, f would equal $268''.2 = 4' \, 28''.2$.

These errors might have been eliminated if both verniers had been read, or if after first set of readings they had been retaken with the telescope reversed (transited), and the means taken. It therefore follows that for all important angles, where accuracy is desired, both verniers ought to be read, or if reading of one vernier is persisted in, the angles should be retaken with the telescope reversed.

2d. *Eccentricity of the Verniers.*—The eccentricity of the verniers is the perpendicular distance between the center of the alidade and a straight

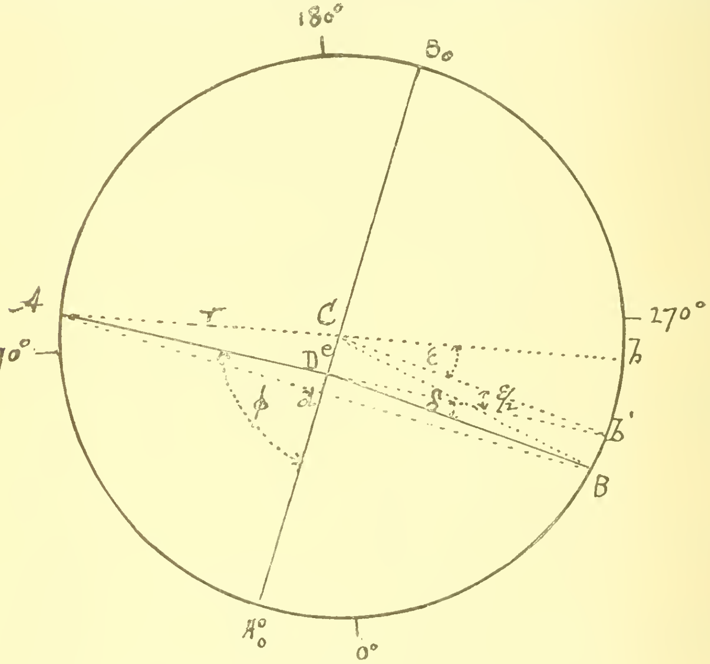


FIG. 2.

line connecting the zero marks of the verniers, or its measure the constant angle which the vernier arms make with each other.

Let Fig. 2 represent the circle of a theodolite.

Let C = center of limb.
D = " " alidade.
r = radius of limb.
A = vernier A.
B = vernier B.
δ = small angle which BD makes with AD prolonged.
Arc $bb' = \varepsilon$ = error due to eccentricity of centers.
e = CD = eccentricity of the centers.
φ = angle which AD makes with CD prolonged.

If now we read the instrument set in position shown in Fig. 2, reading both verniers, we will obtain

$$B - A - 180^\circ = d = \delta + \varepsilon \tag{6}$$

$$\text{or } d = \text{arc } Bb = \text{arc } Bb' + bb' = \delta + \varepsilon.$$

From the small $\triangle\ b'CD$ we obtain the following proportion :

$$sin\ Cb'D : CD = sin\ b'DC : cb'$$

i. e.,

$$sin\ \frac{\varepsilon}{2} : e = sin\ \varphi : r. \tag{7}$$

Since the angle $\frac{\varepsilon}{2}$ is very small, its sine may be taken in terms of arc, and equation (7) becomes

$$\varepsilon = \frac{2\ e\ \rho}{r}\ sin\ \varphi. \tag{8}$$

In which ρ is the radius unity, expressed in terms of arc. When the telescope is reversed, so as to change the vernier arm of A or the angle arm AD of φ, 180°, the absolute value of ε remains unchanged, but it will have the opposite sign. If now for φ in its first position the difference of vernier readings $B - A - 180^\circ$ is d, and the corresponding difference for $\varphi + 180^\circ$ is d', we will have

$$d = \delta + \varepsilon \text{ and } d' = \delta - \varepsilon.$$

or

$$\delta = \frac{d + d'}{2} \tag{9}$$

and

$$\varepsilon = \frac{d - d'}{2} \tag{10}$$

δ is constant, as it only measures the constant angle BDb' of Fig. 2—*i. e.*, the angles which the verniers make with each other ; but ε is dependent upon the angle φ for its value, and therefore varies with that angle.

Hence for determining the value of δ the two component values d and d' would suffice, whereas they would have but little weight in determining the value of ε.

In order to determine the value of ε, we will have to take a number of uniformly distributed observations over the whole limb, and tabulate them as shown below.

The instrument used was a Würdemann, verniers reading to 10″, estimating 5″, six-inch circle :

Ver. A	Ver. B	Ver. A	Ver. B	d	d′	d + d′	d − d′	δ	ε
00°	179° 59′ 55″	180°	00° 00′ 10″	−05″	+10	+05.0	−15.0″	+02.5	−07.5
20°	199 59 55	200	20 00 10	−05	+10	+05.0	−15.0	+02.5	−07.5
40°	219 59 50	220	40 00 10	−10	+10	+00.0	−20.0	+00.0	−10.0
60	239 59 45	240	60 00 20	−15	+20	+05.0	−35.0	+02.5	−17.5
80	259 59 40	260	80 00 20	−20	+20	+00.0	−40.0	+00.0	−20.0
100	279 59 45	280	100 00 20	−15	+20	+05.0	−35.0	+02.5	−17.5
120	299 59 50	300	120 00 10	−10	+10	+00.0	−20.0	+00.0	−10.0
140	319 59 55	320	140 00 10	−05	+10	+05.0	−15.0	+02.5	−07.5
160	340 00 00	340	160 00 05	−00	+05	+05.0	−05.0	+02.5	−02.5

Mean $\delta = +\ 01.7''$.

That is δ, the angle which the arm of vernier B makes with the prolongation of the arm of vernier A, is $+\ 01.7''$;

i. e., the angle around to the left, $ADB = 180^\circ - 01.7''$,

and " " " " right, $ABD = 180^\circ + 01.7''$.

Only one-half the values of ε are given, since for each value of ε that is shown in above table, there is a corresponding value with the opposite sign;

i. e., with ver. A at 40° and ver. B at 220°, $\varepsilon = -10.0''$,

and the corresponding value with

ver. A at 220° and ver. B at 40°, $\varepsilon = +10.0''$.

The values of ε must follow the law of variations of eq. (8), which an inspection of table or a graphical drawing of same will show to be the case (approximately).

Thus it will be seen that for the instrument under consideration, $\varepsilon = 0$ between $\varepsilon = -02.5''$ and $+07.5$, or somewhere between 160° and 180°, or when vernier arm of A lies in the direction of the eccentricity of the centers $CD = e$, then $\varepsilon = 0$, which in this case is somewhere between 160° and 180°, say 170°;

ε being negative when A reads between 350° and 170°;
ε " positive " A " " 170° and 350°;
ε becomes a maximum at 260°, where it equals $+20.0''$;
ε " minimum " 80°, " " $-20.0''$;

which, according to eq. (8), gives

$$\varepsilon = 0 \text{ for } \varphi = 0° \text{ and } \varphi = 180°, \tag{11}$$

$$\text{and } \varepsilon_{\max} = +\frac{2\,e\,\rho}{r}, \text{ and } \varepsilon_{\min} = -\frac{2\,e\rho}{r} \tag{12}$$

Substituting the numerical values obtained from the reduction of the observations in eqs. (11) and (12):

$$\varphi = A + 170° \text{ or } A - 10°; \tag{13}$$

that is, when A reads 0°, $\varphi =$ either $+170°$ or $-10°$;

$$\varepsilon_{\max} = +20'' = \frac{2\,e\,\rho}{r} = \frac{2.e.206265''}{3 \text{ in.}} \tag{14}$$

$$\therefore \quad e = 0.000146 \text{ inches,}$$

which shows the distance CD between the centres to be 0.000146 inches, and that its azimuth lies in the direction of the 170° mark on the limb.

From $\delta = 01''7$ we obtain the value of $Dd = e'$ the eccentricity of the verniers; *i. e.*, from Fig. 2, we find

$$e' = \frac{r\,\delta}{2\,\rho} \tag{15}$$

The numerical values being substituted.

$$e' = \frac{3 \times 1.7}{2 \times 206265''} = \frac{5.1}{413530} = 0.000012 \text{ inches.}$$

When these instrumental errors are to be weighted in a system of observations of the higher orders of work, the examinations are minutely and accurately determined, and reduction made by the rigid method of least squares. An example illustrative of this point may be found in Jordan's Handbuch der Vermessungskunde, Vol. I.

An examination of the table shows that e and e' are very small, but still they exert a perceptible influence on the readings of the verniers, varying from $0''$ to $\pm 20''$ according to position of the reading.

This effect should always be eliminated from all angles which mark important boundaries, and which, when once fixed, are to be the standard

for future reference ; or from all angles for which any degree of excellence is claimed.

To eliminate the effect of eccentricity, the observations should give as many readings of the $-\varepsilon$'s as of the $+\varepsilon$'s ; *i. e., in reading an angle the observations should show an equal number of uniformly distributed readings with the telescope direct and with it reversed by transiting in Y's.*

B.—Eccentricity of the Telescope.

Let Fig. 3 represent the circle of a theodolite whose telescope is not mounted directly over the centre C, but at a distance of $CD = e$ measured on a perpendicular let fall from C.

AB is the line joining the zeros of verniers when telescope DE is pointed at L.

And $A'B'$ the line joining the zeros of verniers when telescope DE or $D'E'$ is pointed at R.

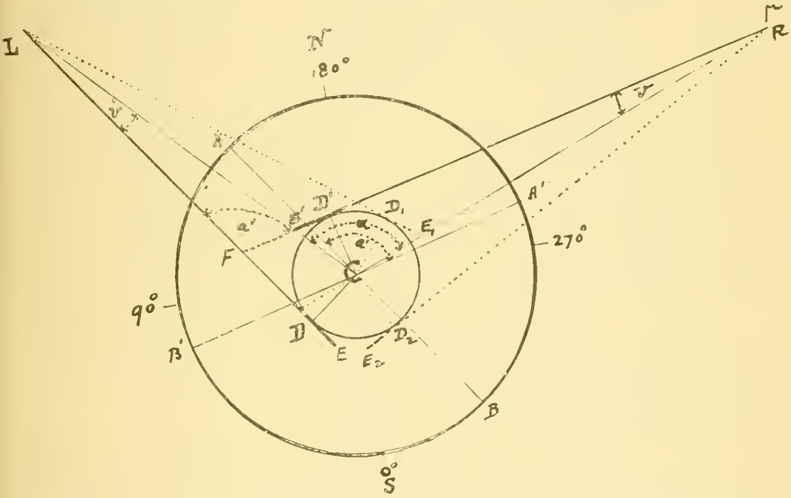


FIG. 3.

$\angle\ LCR = a =$ the true angle between L and R.

$\angle\ ACA' = a' =$ the angle read by verniers when telescope is eccentric.

$NS = 180° - 0°$ line—or line of true meridian with the azimuth taken from the 0° in the south around to left, through the west, north, east, back again to the south (same as the astronomical azimuths). When the telescope is directed to L, the arc $AS = r'$ will be the reading of vernier A ; when telescope is directed to R, the arc $A'S = r''$ will be the reading of vernier A.

Then $r'' - r' = \angle\ ACA' = \angle\ LFR = a'$, which differs from the true value a by a small correction due to the eccentric position of the telescope. This correctioh or error f is equal to $a' - a$. From Fig. (3),

$$L\ E'R = a + v = a' + v', \text{ which gives}$$

$$a = a' + v' - v. \qquad (16)$$

The angles v and v' are quite small, and as they depend entirely upon the relation between the angle arms $CR = l$ and $CL = l'$ and the ec-

centricity $CD = CD' = e$, we can obtain v and v' in terms of e, l and l', viz.:

From the small triangles RCD' and LCD

$l \sin v = e$ and $l' \sin v' = e$, which, expressed in terms of seconds of arc, gives:

$$v = 206265'' \frac{e}{l} \text{ and } v' = 206265 \frac{e}{l'} \tag{17}$$

Substituting the values of (17) in eq. (16), we have:

$$a = a' + 206265\, e \left(\frac{1}{l'} - \frac{1}{l}\right) \tag{18}$$

$$\text{or } a - a' = f = 206265\, e \left(\frac{1}{l'} - \frac{1}{l}\right) \tag{19}$$

Eq. (18) shows how the true angle a may be obtained from the measured angle a' and the elements of eccentricity e, l and l', and eq. (19) gives the influence of this eccentricity on any angle knowing e, l and l'.

From both (18) and (19) it will be seen that when $l = l'$, $f = 0$; f increases with the increase of e and the difference between l and l'.

When $e = 0.004$ inches, $l' = 10$ ft and $l = 2\,l' = 20$ ft., $f = \frac{825.''06}{240} = 3.''5$, a small quantity, it is true, but of sufficient importance to show that when the angle arms of an angle are unequal and any importance is attached to the measured value, the work should have been so arranged as to eliminate the error.

To eliminate this error, transit or reverse the telescope, and without disturbing the limb reread the angle and take the mean of the results. The second operation gives

$$a = a'' - v' + v, \tag{20}$$

as will be seen on an inspection of Fig. 3. The verniers would fall at B and B', giving the arc $SAB = r_{,}$ and arc $SB' = r_{,,}$; $r_{,,} - r_{,} = a''$, the value of the angle as read.

Taking the mean of eq. (16) and (20) we have

$$a = \tfrac{1}{2}(a' + a'') \tag{21}$$

In the above discussion it was supposed that the alidade had no eccentricity, hence only one vernier was indicated as read. But as no instrument is without more or less eccentricity between alidade, limb and verniers, both verniers should have been read both before and after reversal. The reading of both verniers before reversal would not eliminate the effects of the eccentricity of the telescope, but only eccentricity of the verniers. Reading both verniers after reversal and taking mean of all the readings, not only eliminates the effects of the eccentric telescope, but also the error of eccentricity of centres of alidade and limb and eccentricity of the verniers.

C.—Inclination of the Limb.

That is, the plane of the limb is slightly inclined to the vertical axis. The error due to the inclination of the limb is not so much due to the fact that the visual planes passing through the line of collimation do not project the angles upon a horizontal plane, as to the fact that these planes, owing to the construction of the instrument, are not vertical. If it were possible to project the vertical angles by a system of vertical planes, independent of the mechanism, the inclination of the limb

would have to be very great to show an appreciable influence upon the horizontal angles between points not lying in the same plane.

Let C be the position of the centre of the instrument. Let A and B be two points in space between which the horizontal angle is to be measured, A being on a horizontal line passing through C, and B elevated on the line BC. Were the instrument in perfect adjustment, the projected angle upon the horizontal plane passing through C and coinciding with the plane of the limb, would give the desired angle. In Fig. 4, let

AH represent the trace of the horizontal plane passing through C,

AH' the trace of the limb inclined to the horizontal plane by the angle γ,

AB the trace of the inclined plane passing through A, B and C, and inclined to the plane of the horizon by the angle ε,

$B\,H'$ the trace of a plane through B and C passed perpendicular to the plane of the limb, and

$B\,H$ the trace of plane through B and C passed perpendicular to the plane of the horizon.

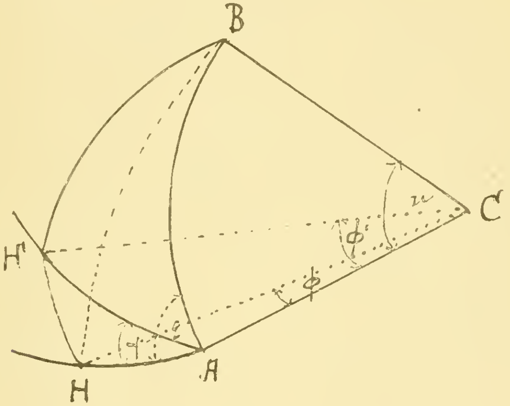


FIG. 4.

α = angle of elevation of B above the horizon $= \angle\, BCH$.

φ = true projection of the inclined angle ACB.

φ' = projection of same plane ACB upon the plane of the limb AH'.

δ = $\varphi' - \varphi$ = error due to the inclination of the limb.

With C as the centre, a sphere is supposed to have been described with a radius $r = 1$, whose equatorial arc coincides with the trace AH, or horizon. Compiling the above angles and arcs for ready reference:

Let arc $A\,B = \angle\, ACB = u$ $\qquad \angle\, BAH = \varepsilon$

" " $A\,H = \angle\, ACH = \varphi$ $\qquad \angle\, HAH' = \gamma$

" " $A\,H' = \angle\, ACH' = \varphi'$

" " $B\,H = \angle\, BCH = \alpha$

hence from the right-angled spherical triangle ABH we obtain:

$$Cot\ \varepsilon = sin\ \varphi\ cot\ \alpha. \tag{22}$$

And
$$tan\ \varphi = cos\ \varepsilon\ tan\ u. \tag{23}$$

And from the right-angled spherical triangle BAH'

$$tan\ \varphi' = cos\,(\varepsilon - \gamma)\ tan\ u. \tag{24}$$

With the aid of these equations the error $\delta = \varphi' - \varphi$ may be readily determined.

When α and φ are given, the value of ε can be obtained from eq. (22), which when substituted in eq. (23) gives us the value of n, and u substituted in eq. (24) gives us φ'. If it is desired to obtain φ' directly from the values of φ, α and γ, we can eliminate the values of u and ε by taking eq. (24), and with the aid of eq. (22) and (23) obtain :

$$Tan\ \varphi' = cos\ \gamma\ tan\ \varphi + tan\ \alpha\ sin\ \gamma\ \sec.\ \varphi. \tag{25}$$

From a well-known trigonometrical formula,

$$(1 + tan\ \varphi'\ tan\ \varphi)\ tan\ (\varphi' - \varphi) = tan\ \varphi' - tan\ \varphi. \tag{26}$$

Substituting the value of $tan\ \varphi'$ from eq. (25), and calling

$$tan\ \alpha\ sin\ \gamma - sin\ \varphi\ (1 - cos\ \gamma) = p, \tag{27}$$

eq. (26) or $tan\ \delta = tan\ (\varphi' - \varphi)$ becomes

$$Tan\ \delta = \frac{p\ cos\ \varphi}{1 + p\ sin\ \varphi} \tag{28}$$

or δ in terms of seconds of arc becomes :

$$\delta = 206265''\ \frac{p\ cos\ \varphi}{1 + p\ sin\ \varphi}. \tag{29}$$

If $\varphi = 30^\circ$, $\gamma = 1'$ and $\alpha = 10^\circ$, then $p = 0.00004341$ and $\delta = 0^\circ—0'—05''.4$.

If $\varphi = 30^\circ$, $\gamma = 1^\circ$ and $\alpha = 10^\circ$, then $p = 0.00302$ and $\delta = 0^\circ—8'—57''$. If the angle φ had been 60°, and half the angle laid 10° above and the other half 10° below the horizon, the second half would also give $\delta' = 0^\circ—8'—57''$ and the total error $\Delta = \delta + \delta' = 0^\circ—17'—54''$. When $\varphi = 90^\circ$, δ becomes 0, and when $\varphi = 0$, $\delta = 206265''\ p = 206265''\ tan\ \alpha\ sin\ \gamma$, in which case the angle φ would lie in a vertical plane, *i. e.*, the points A and B would lie vertically over each other. If one of the angle arms was inclined at an angle of 45° and the other horizontal, $tan\ \delta = sin\ \gamma$ or $\delta = \gamma$ approx. In other words, were the limb inclined 1° or 1′, the reading on the horizontal circle would show a value of 1° or 1′ for φ, whereas it in reality ought to be zero. From this it will be seen of how much importance it is to have the limb horizontal, especially in measuring angles on slopes, etc.

The influence of this error can be eliminated by taking readings with telescope direct and reversed (transited), and shifting the limb 180° in azimuth after reversing telescope, and taking the mean of the readings, provided that in so doing the limb would be dipped in the opposite direction.

If the limb does not dip in an opposite direction from the first, after reversal, careful leveling of the plate of limb is the only recourse.

As the alidade carries not only the telescope and verniers, but also the levels, the horizontal position of the limb of each instrument ought to be separately examined for successive leveled positions of the alidade.

This is done by carefully removing the alidade after it has been leveled for each of the various positions around the full circle, and trying the limb by placing an adjusted level upon it, for each of the corresponding positions of the alidade—say at intervals of 30° around the circle. The amount of the deflection can be readily computed from the level readings, and with the help of the above formulæ, its influence on any angle may be found. If the error is large enough to affect the value of the measured angles, the programme for measuring angles will have to be arranged so as to eliminate it.

D.—Inclination of the Line of Collimation.

If the plane of the limb is horizontal, and the visual plane passing through the line of collimation is inclined to it by an angle γ, to find the effect of this error:

In Fig. 5, let $\angle ACB$ be the angle whose horizontal projection is to be measured; the two points A and B being situated above the horizontal plane $DA'EB'C$ or the plane of the limb, AC and BC being the angle arms; the angle of elevation of AC being α, and the angle of elevation of BC being β.

Describing a sphere whose radius $CD = CE = 1$, from C as a centre, AA' will be the trace on the sphere of a plane passed through AC, perpendicular to $DA'EB'$, and BB' will be trace of a plane passed through BC, perpendicular to same plane. The traces cut out by the visual plane passing through AC and BC will be AD and BE respectively.

Let $A'CB' = \varphi =$ true horizontal angle, and

$DCE = \varphi' =$ erroneously measured angle.

CD, the trace of the visual plane, passing through AC, on the horizontal plane, will be erroneous by ε.

CE, the trace of the visual plane passing through BC on the horizontal plane, will be erroneous by ε', and the combined error will therefore be δ, or, in above case, $\delta = \varepsilon - \varepsilon'$. If BC were below the horizon, δ' would be equal to $\varepsilon + \varepsilon'$.

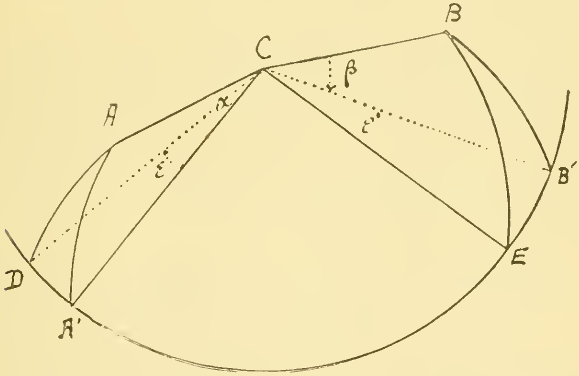


FIG. 5.

The values of ε and ε' are determined from the right-angled spherical triangles ADA' and BEB'. Since arc $A'D = \varepsilon$, arc $AA' = \alpha$, $AA'D = 90°$ and $\angle ADA' = 90° - \gamma$, where γ is the angle of inclination of visual plane toward the vertical, we have

$$\sin \varepsilon = \tan \alpha \tan \gamma. \tag{30.}$$

In the $\triangle BEB'$ the arc $B'E = \varepsilon'$, arc $BB' = \beta$, $\angle BB'E = 90°$ and $\angle BEB' = 90° - \gamma$, whence

$$\sin \varepsilon' = \tan \beta \tan \gamma. \tag{31.}$$

Since ε and ε' are very small angles, their sines may be expressed in terms of seconds of arc, and equations (30) and (31) become

$$\varepsilon = 206265'' \tan \alpha \tan \gamma \tag{32.}$$

$$\varepsilon' = 206265'' \tan \beta \tan \gamma \tag{33.}$$

$$\text{and } \delta = \varepsilon - \varepsilon' = 206265'' \tan \gamma (\tan \alpha - \tan \beta). \tag{34.}$$

in which α and β are positive for angles of elevation, and negative for angles of depression.

i. e., if $B\ C$ were inclined below the horizon, β becomes negative, then

$$\delta' = 206265'' \tan \gamma (\tan \alpha + \tan \beta) \tag{35}$$

when $\alpha = +20°$, $\beta = -20°$ and $\gamma = 5'$, then $\delta = \varepsilon + \varepsilon' = 218''.4 = 3' - 38''.4$. This error of $3' - 38''.4$ is the same for all horizontal angles between A and B, no matter how large or small they may be, even for an angle very nearly zero ; *i. e.*, if A and B were situated in space vertically over each other, the reading on the limb would indicate a reading of $3' - 38''.4$, or as near to it as instrument could be read. If A and B were situated at the same elevation above or below the horizontal plane, *i. e.*, $\pm \alpha = \pm \beta$, there would be no error made in reading the horizontal angle. But, as a rule, no two points are found to lie exactly in the same horizontal plane, above or below the horizon. Such being the case, it will be seen from the above that it is very important to have the line of collimation travel in a vertical plane perpendicular to the horizon. The influence of this error, however great or small, may be eliminated by retaking the readings with the telescope reversed (transited) without disturbing the position of the limb, and taking the mean of the two results obtained.

Combined Errors.

To find what influence the combined errors would have, the instrument would have to be carefully tested, each source of error observed, and the corrections for various angles noted, with the help of which we may obtain the value of the combined errors and their influences. The most unfavorable condition is to suppose that all the errors occur in one direction, *i. e.*, positive or negative. This, however, is not probable, as generally they are more or less compensating.

Thus if

$\pm \delta_1 =$ mean error due to eccentricity of the alidade and limb verniers :
$\pm \delta_2 =$ " " " telescope ;
$\pm \delta_3 =$ " the inclination of the limb ;
$\pm \delta_4 =$ " " " " line of collimation:

the total mean error $\triangle$ would not be equal the sum of all or $\pm \Sigma(\delta)$, but from the theory of probabilities the mean error

$$\triangle = \pm \sqrt{\delta_1^2 + \delta_2^2 + \delta_3^2 + \delta_4^2} = \pm \sqrt{\Sigma\left(\delta\ \delta\right)}.$$

In other words if each δ was equal to $\pm$ 10″ the combined error would not be $\triangle = \pm 40$ but $= \pm \sqrt{400} = \pm 20''$.

Summary.—It will be seen from the above discussion, that in order to insure any sort of reliability in work a theodolite ought always to be used as a non-repeater, with the telescope direct and reversed ; reading both verniers for each position of the telescope, and in order to counteract the slip, station twist, etc., read to all the points desired from the station occupied, first in the positive direction (with the graduation) of the circle, then backward in the negative direction for each position of the telescope. When only one set of readings is to be taken the telescope should be in a direct position while working positively and reversed while working negatively. When more accurate results are desired, a greater number of sets should be taken ; the circle is shifted a proportional part of 180°

according to the number of results to be obtained, the direct and reversed positions of the telescope alternating. Of course, where the nearest minute that can be obtained from one pointing will suffice, the above refinements would not be necessary.

But where any horizontal angle is to be measured and become a matter of important record, a programme similar to the above should be followed. I have heard of instances where great accuracy was claimed for angles where several sets of repetitions were taken and *one* vernier only read, without even reversing telescope or shifting the circle. The results may have been good enough to answer the purpose for which they were taken, but it has no proper claim to *great accuracy.*

A *second* vernier reading would have added greatly to its value, but even then there are too many sources of uneliminated errors remaining, to stand test of accuracy—it may be good enough, but it is not accurate.

The engineer's transit, or theodolite, is nothing more than what is known as a repeating instrument.

The repeater as a measurer of angles is conceded by all geometricians to work better in theory than in practice. It has two vertical axes, and it is a difficult matter to make them perfectly concentric—this gives an eccentricity. This, *with* the unavoidable slips and many sources of accidental errors, has led to the abandoning of the method of reading angles with repeaters, in late years, in the higher orders of work, and led to the substitution and almost exclusive use of the non-repeaters.

With the repeater it often becomes a question whether the alidade or limb is to be leveled.

When the axis of the limb is vertical, as the work of repeating goes forward the inclined axis of the alidade describes a conical surface about the limb's axis; and when the axis of alidade is vertical at the beginning of a repetition, and limb's axis inclined, while repeating, the alidade axis will revolve around with the limb's axis, each axis describing a conical surface, making error twice as large as in former case. Time is too limited to discuss this point to any further length, but I would like to add, that if an angle is to be measured with a repeating instrument by repetitions, select your programme in such a manner that the eccentricity of the limb and alidade are eliminated. Thus: with the telescope direct, repeat the smallest angle in your series until it has made at least one complete circuit of the circle, *i. e.*, from 0° to 360°, first in positive direction, then in a negative direction of the circle with telescope reversed, reading both verniers, and take the mean. This makes one set.

When more than one set for an angle is required, shift the circle so that the space from 0° to 180° will be divided into parts equal to the number of sets desired; the sets then should alternate with telescope direct and reversed, working positively and negatively as before.

The above is the programme for the smallest angle; a larger angle to have an equal weight would have to be repeated as many times as the smaller, a long and laborious process. Even with all these precautions the result as a result does not compare with that which could have been obtained in an equal time, and with equal care, by using same instrument as a non-repeater with a proper programme.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 21, 1885:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:40 P. M. Vice-President L. Frederick Rice in the chair; twenty-nine members and three visitors present.

The record of the last regular meeting and that of January 14, 1885, were read and approved.

The Treasurer submitted a statement of the condition of the finances of the Society from which it appeared that a Burlington and Missouri River R. R. bond belonging to the Society had been called. On motion of the Treasurer it was voted: That a committee be appointed by the Chair to recommend a proper investment of such portion of the funds as the Treasurer may deem expedient.

The Chair appointed as that Committee Messrs. Philbrick, Bradley and Wightman.

On motion it was voted: That a committee be appointed by the Chair to arrange for the annual dinner.

The Chair appointed as that Committee Mr. Henry Manley.

The Government presented its report in favor of furnishing a copy of the JOURNAL of the Association of Engineering Societies to the Boston Public Library and to the Massachusetts State Library.

Messrs. Alexander L. Kidd and Arthur H. Howland were elected members of the Society.

Mr. Ralph A. Quimby was proposed for membership recommended by Thomas H. Davis and Thomas J. Young.

Mr. Edward A. W. Hammat was proposed for membership, recommended by Messrs. Henry Manley and M. M. Tidd.

Mr. H. A. Carson read a paper on the Cross Sections of Sewers and Conduits.

Discussion followed by Messrs. Stearns, Rice, Clarke and Manley.

Mr. F. P. Stearns exhibited diagrams showing the comparative cost of sewers of circular section and conduits with abutments.

Mr. Dexter Bracket exhibited diagrams showing settlement and change of form of cross section of the Mystic Water-Works Conduit.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

FEBRUARY 18, 1885:—The Club was called to order at 8:15 P. M., by President Moore. There were thirty-five members present.

The minutes of the last meeting were read and approved. The Executive Committee recommended the election to membership of the following gentlemen:

D. E. Condon, J. T. Desmond, P. M. Bruner.

They were unanimously elected by ballot.

Mr. Henry B. Wood was proposed for membership by Messrs. J. A. Ockerson and K. Tully.

A paper by Mr. Thos. H. Macklind on "Street Pavements," was then read, and discussed by the Club.

Mr. Hubert P. Taussig then read a paper on "Improvements in Switches," which was generally discussed.

[*Adjourned.*] THOS. D. MILLER, Secretary.

MARCH 4, 1885:—The Club was called to order at 8:15 P. M. by President Moore, twenty-two members and three visitors being present.

The Executive Committee recommended that Mr. Henry B. Wood be elected a member of the Club; being balloted for, he was declared unanimously elected.

The next order of business was the reading of a paper on "Treatment of Wood for Street Pavements," by Messrs. Caldwell & Miller. It was discussed by Messrs. Constable, Johnson, Robt. Moore, H. C. Moore and Lansden. Mr. Theo. Plate, President American Wood Preserving Company, being present, was called on to give his views. He expressed it as his opinion that the idea that gum wood was a cheap wood, was a mistake, because when all heart wood was required it necessitated more work and consequently greater expense in securing it, than has heretofore been supposed.

Mr. Lansden exhibited a section of water-pipe from Fall River, Mass., which had lain about eighteen months in a bed of cinders, where it was submerged in tide water twice in twenty-four hours. It had disintegrated two-thirds of the way through, leaving a substance as soft as graphite, the pitch coating of the pipe still being plainly visible both inside and out.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

FEBRUARY 17, 1885:—The 203d meeting was held at 4 P. M., President Williams in the chair.

The minutes of the preceding meeting were read and approved.

The committee appointed to report on the suggestions made by Vice-President Chanute at the last meeting made the following

REPORT:

1. The Secretary to communicate with the Secretary of the Association in regard to the plan proposed by Vice-President Chanute for joint discussion of papers by the different Societies of the Association.

2. A committee of three to be appointed to prepare a list of engineering subjects upon which the Society would invite papers.

3. A committee of three to be appointed to report upon a plan for securing an endowment fund, the revenue of which shall be devoted to the award of annual prizes for the best paper contributed by a member.

This report was adopted.

Mr. Morehouse presented the following as amendments to the Constitution and By-Laws:

ARTICLE III. OF CONSTITUTION.

Add as *Section* 3. The President and Vice-President shall not be eligible for election to the same respective offices for a second consecutive term.

ARTICLE V. OF BY-LAWS.

Section 2. Amend to read, "The admission fee for Associates shall be ten dollars." All after these words to be omitted.

On motion of Mr. Cregier the proposed amendment to the Constitution was laid on the table.

The Secretary read a letter from Mr. E. B. Noyes, a former member of the Society, requesting signatures to a petition to the President of the United States, asking that a Civil Engineer be appointed to the position of Chief of the Bureau of Yards and Docks of the Navy Department.

The Chair suggested that such members as were in accord with the petition should affix their names to it.

The President having requested Mr. Green to take the chair, read a paper, "The Separate *vs.* the Combined System of Sewerage as Exemplified in the Drainage of Hyde Park," illustrated by maps and plans.

After discussion of the paper, the Secretary presented a paper by Mr. R. Frank Hartford, "Some New Sewer Formulæ."

Reading of this was postponed to the next meeting.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

MARCH 3, 1885 :—The 204th meeting was held at 4 P. M. Mr. Randolph was called to the chair.

The minutes of the preceding meeting were read and approved.

The Secretary read a letter from President Williams, appointing the committees voted at the last meeting :

On Topics : Messrs. Artinstall, Cole and J. Nichol.

On Endowment Fund : Messrs. Chanute, Cregier and Green.

The Secretary read the paper presented at the last meeting by Mr. R. F. Hartford, "Some New Sewer Formulæ." Mr. Cooley offered the following, which was seconded by Mr. Cregier, and unanimously adopted :

Resolved : That President Williams be, and is hereby, requested to continue his valuable services as the representative of this Society in the Association of Engineering Societies.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. IV. April, 1885. No. 6.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

DESCRIPTION OF THE FOUNDATION PLACED BENEATH THE PUMPS AND ENGINES AT THE NEWTON, MASS., PUMPING STATION.

BY ALBERT F. NOYES, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read February 18, 1885.]

The Newton Pumping Station is situated about one-fourth of a mile east of the Newton Upper Falls Station of the Woonsocket Division of the New York and New England Railroad. The site upon which it is erected was formerly a marshy piece of land, full of springs, with a high gravel hill to the north and the Charles River to the south. The elevation of the natural surface of the ground was between grades 93 and 94. The normal height of the water in the river is grade 91, with a minimum and maximum height between grades 89 and 93. Borings made before construction showed that there were from eighteen inches to two feet of muck, one to two feet of clayey quicksand, four to six feet of sandy gravel, and twenty to thirty feet of fine quicksand, under which there appeared to be a sandy gravel full of boulders or stone, and it was with difficulty that a pipe could be forced beneath the sand. The building is a one-story brick structure, 100 feet by 50 and 52 feet, with a boiler-room in the rear and a wing adjoining the boiler-room, occupied by coal etc., 41 feet by 44 feet 10 inches. The pump well was 9 feet 10 inches by 29 feet 9 inches, and about 15 feet deep inside. The front wall of the building stands on one of the side walls of the well, so that the well occupies nearly the whole front of the basement of the building. The bottom of the well was a tight platform of Georgia pine, and the walls are of brick masonry. From the pump well to a screen chamber about 56 feet from the building, a culvert (3 feet by 3 feet 6 inches in the clear) was built of uncut granite masonry, laid in mortar.

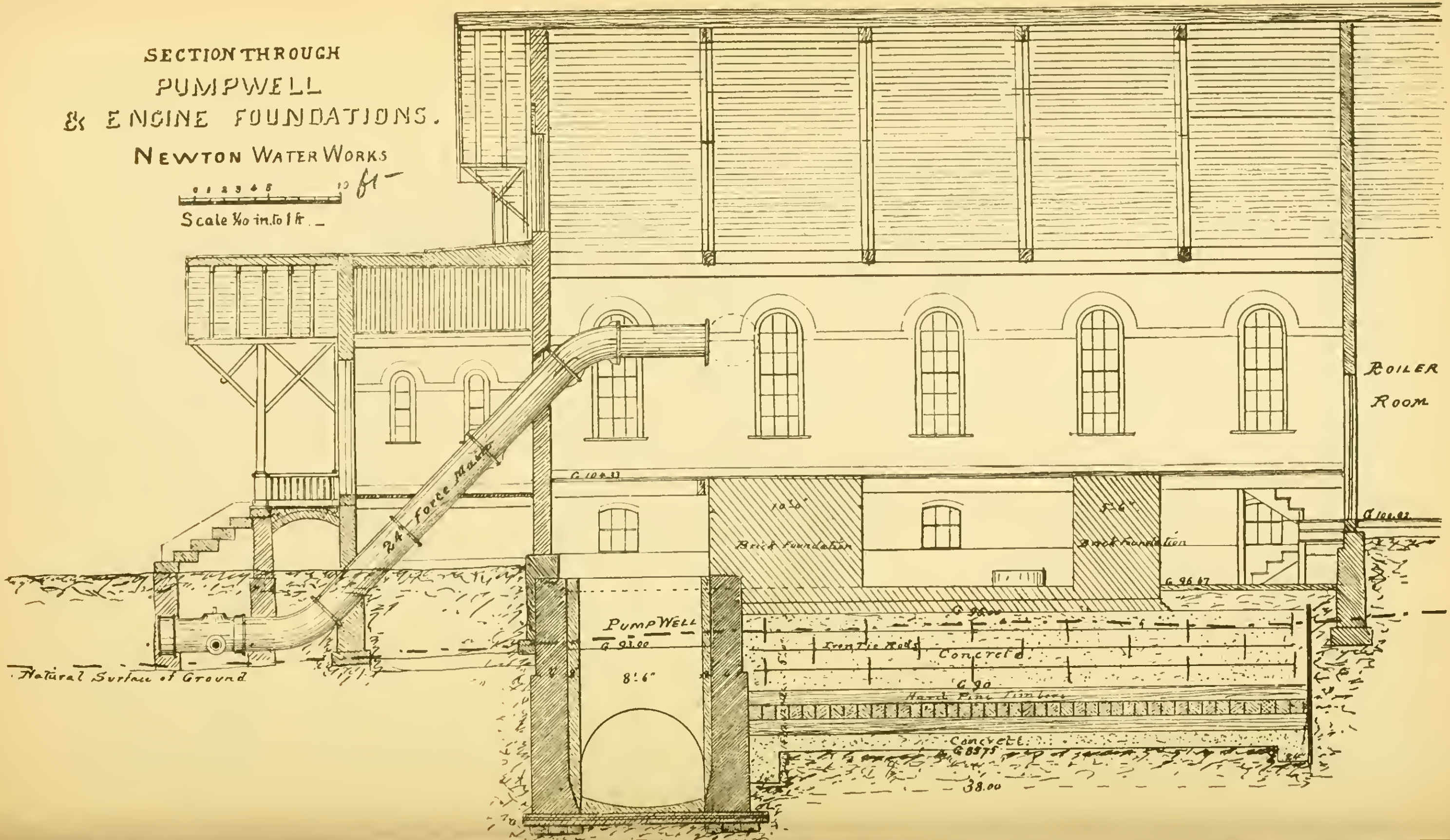
The pumps and engines were made by Henry R. Worthington, of New York. The water plungers of the pumps are 20 inches and 22.5 inches in diameter, and have a 50-inch stroke. The engines are compound,

duplex condensing, with high-pressure cylinders of 30 inches diameter, and low-pressure cylinders of 51 inches diameter.

The front ends of the piers supporting the pumps rested on one of the side walls of the pump well, while the rear ends and engine piers rested upon a foundation of brickwork 15 inches thick. The first settlement or change in the alignment of the engines and pumps took place soon after the duty test in 1877, and continued so that realignments had to be made every six to nine months, which involved considerable expense, aside from the liability of cutting the piston rods and steam cylinders. These changes were uneven, being for the most part toward the north, with the front and rear ends of the engines and pumps canting toward each other; thus, in effect, doubling the actual change. During the construction of the pump well and conduit, considerable difficulty was encountered with quicksand, and the platform upon which the walls of the well were built settled at the north end (according to the Engineer's report of 1877) about five inches. This caused sundry cracks in the brickwork, which was in part rebuilt. My attention was first called officially to the trouble early in the year of 1880. An examination of the pump well showed several cracks through which the ground-water was flowing. In the conduit there was from four to ten inches of quicksand, and a strong inflow of ground water and sand from between the bottom stones. This in itself seemed sufficient cause for the settlement, and it was determined to continue the 24-inch pipe to the well in the place of the conduit.

As one of the chief difficulties presented in the execution of this work, was the stopping of the inflow of the ground water and quicksand, upon which the conduit was built, the method employed may be of interest. Instead of sinking a well ahead of the general excavation, and pumping directly from it, eight 1½-inch pipes, placed about fifteen feet apart, were driven to a stratum of coarse sand or gravel, about 35 feet deep. To the ends of the pipes were attached the ordinary sand strainer, terminating in a sharp, solid point. These strainers were composed of a perforated iron pipe, about 2 feet long, surrounded by a fine strainer of perforated brass. These pipes were connected together and attached to a small Blake pump. The ground water was so lowered that the excavation was made in dry ground, excepting at a point directly beneath the foundation of the building, where, although greatly checked, a considerable flow continued, which had to be taken care of with a hand pump. The stopping of the leak in the conduit diminished the frequency of the settlement, and upon the recommendation of Mr. Wm. E. Worthen, of New York, who was employed as consulting engineer, the foundations to the pumps and engines were enlarged by placing cement concrete around the piers, five feet in width (extending three feet under and two feet outside of the pier) and two feet in thickness. The piers were first shored and braced up so as to prevent, if possible, any settlement during the excavation underneath them; this having been accomplished, excavation was begun. Small sections of about three feet in width and extending under the foundation to the extreme depth and width required, were removed, and a cement concrete, consisting of four parts clean stone, two parts sand and one part Newark cement, was rammed into the excavation; this

SECTION THROUGH
PUMPWELL
& ENGINE FOUNDATIONS.
NEWTON WATER WORKS

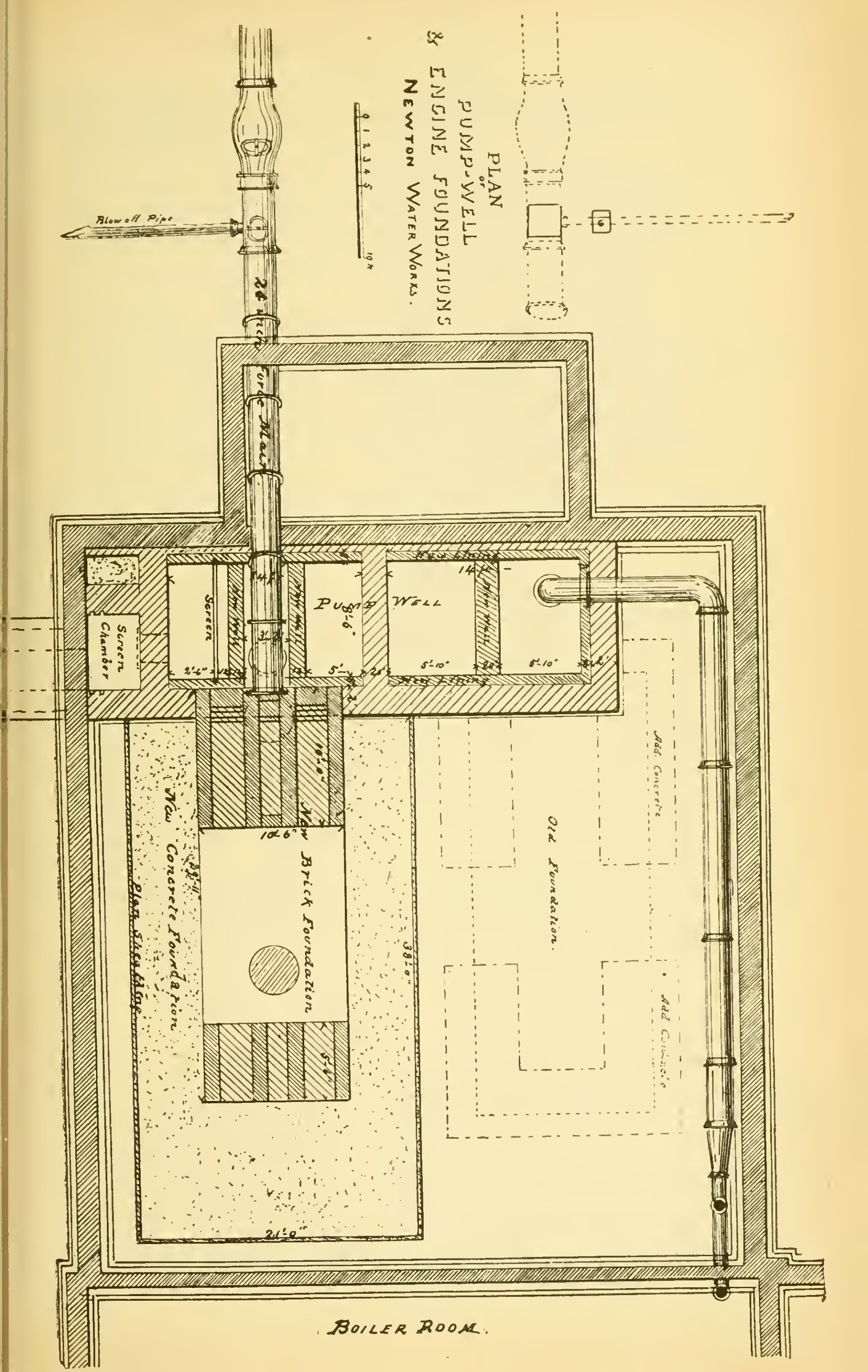


was thoroughly worked and rammed solid. These sections were allowed to stand at least two days, and generally three days before the next section to them was excavated; this was done to prevent, as far as possible, any strain being brought to bear on the concrete before it was thoroughly set. In excavating for these sections, water was reached at a depth of about 18 inches from the top; this showed that the leaks in the conduit had been stopped and that the ground water was returning or had returned to its normal height.

The settlement of the large pumping-engine continuing through the year 1881, with no apparent prospect of ceasing, the Water Committee voted early in the year 1882 to try a plan for a quick and easy alignment of the pumps after each settlement, as recommended by Mr. William E. Worthen, consulting engineer. The plan was to rest the pumps and steam cylinders upon long, thin oak or steel wedges, instead of on sulphur-beds, as heretofore. Should a slight settlement occur, it was designed that the wedges should be started, and the axis of the cylinders in the pumps and engines brought into the same plane. But, owing to the irregularity in the surface of the castings, each wedge and each face had to be refitted after each alignment. As this would entail a larger expense than by renewing the sulphur-bed, the Committee decided to put the engines and pumps on a new foundation.

In accordance with their instructions, the following plan for the new foundations was submitted, and adopted by them:

The building was carefully shored up so that but little of the weight of the walls rested on their foundations, and any settlement which might occur would not injure the building. An excavation was made the full size of the interior of the building, except such portions as were occupied by the engines and pumps. The sides of the excavation were carefully sheeted and braced, and the excavation carried to a depth of eleven and twelve feet. A trench one foot deep and two feet wide was excavated around the edge of the excavation, and filled with Portland cement concrete, which was carried fifteen inches above and over the bottom of the whole excavation. Upon this a solid bed of $12'' \times 12''$ hard pine timbers was laid parallel to the pumps, and thoroughly tree-nailed together with $1\frac{1}{4}''$ locust tree-nails twenty inches or more long, and bedded in fresh cement mortar. Upon this another layer of $12'' \times 12''$ timber was laid, at right angles to the first, and each cross of timber having a tree-nail, as above. A third course was laid, as above, parallel to the first, and the whole covered with a bed of Rosendale cement concrete four and one-half feet thick, and Portland cement concrete six inches thick, and leveled off twelve inches below the basement floor. Upon this was laid the brick-work for the floors and piers. The main body of concrete was strengthened and welded together by imbedding eighteen strips of $2\frac{1}{2}'' \times \frac{3}{8}''$ wrought iron, with split and turned ends, laid crosswise, and nine strips laid longitudinally in the concrete in three layers of six and three each. All cracks in the building were carefully pointed, so that any subsequent settlement can be detected. Although the excavation was made several feet below the foundation of the building, in running sand, gravel, and quicksand, no sign of a settlement has been apparent as yet.

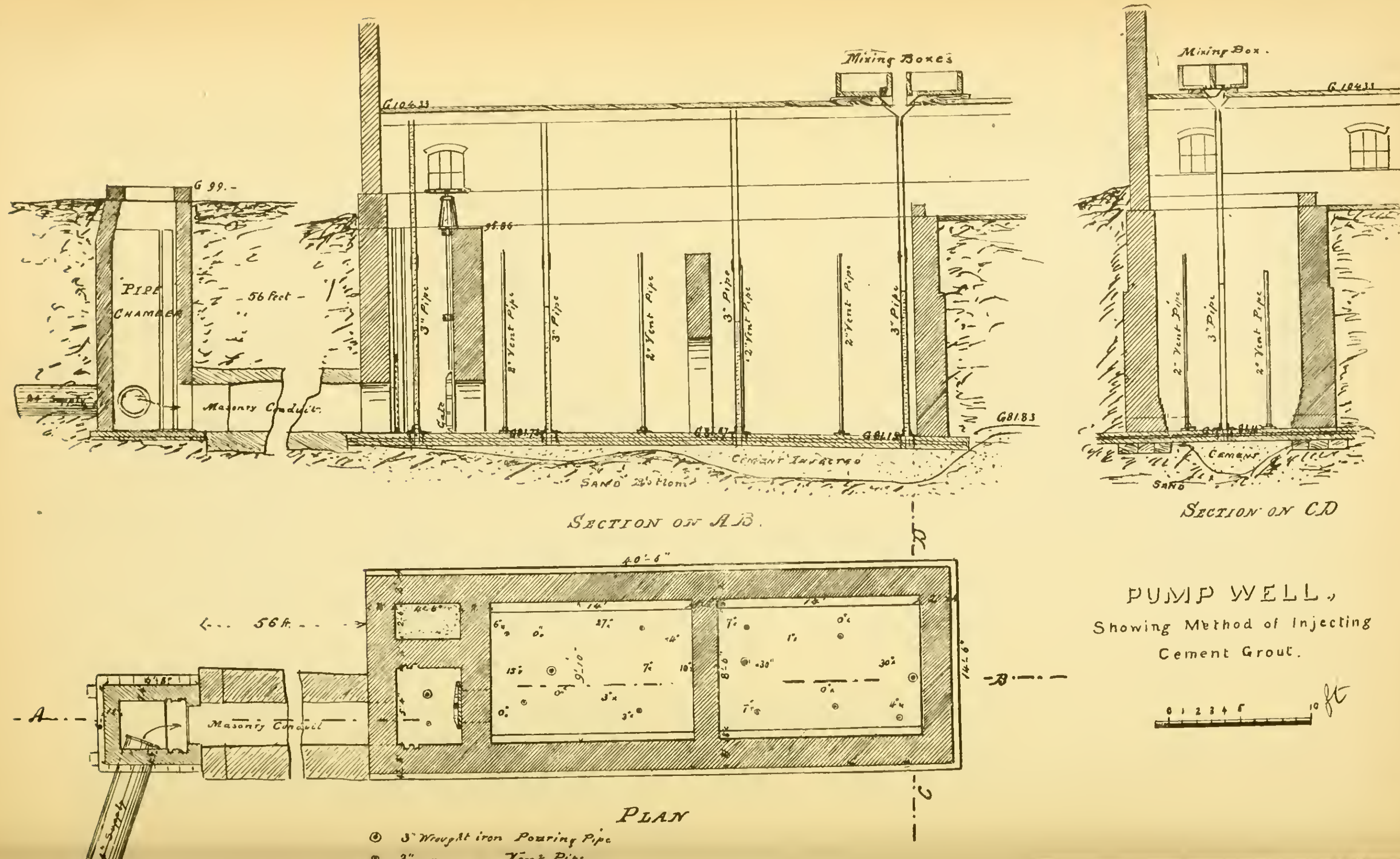

PLAN
of
PUMP-WELL
& ENGINE FOUNDATIONS
NEWTON WATER WORKS.
Blow off Pipe
Screen Chamber
Screen
PUMP WELL
New Brick Foundation
New Concrete Foundation
Old Foundation
Add. Concrete
10'6"
21'0"
38'0"
BOILER ROOM.

Feeling that there might still be cavities beneath the planking of the pump-well, borings were made with a quarter-inch bell-hanger's auger, which showed that spaces existed under nearly the whole bottom of the well, varying in depth from nothing to 10 or more inches. It was therefore decided to inject cement-grout under the plank, in order to make everything as solid as possible. The well was 29 feet 9 inches long by 9 feet 10 inches wide and about 15 feet deep, with a screen and gate-chamber 5 feet 4 inches by 4 feet 6 inches, of the same depth as the main well.

As the water-pressure against the bottom of the well, when empty, was equal to 10 feet of head, it was necessary to bore through the planking under a head equal to that in the ground outside. Cast-iron flanges were made fast to the plank bottom by lag-screws. A length of 3-inch pipe 12 feet long was screwed into the flange. The pipe was filled with water and the plank bored with a long-handled auger. To insure the perfect filling of all cavities, four of these 3-inch pipes were placed equi-distant from each other through the centre of the well, and ten 2-inch pipes, used merely for vents, were placed on the extreme sides and corners of the well. The main 3-inch pipes were carried to the level of the engine-room floor by the addition of a length of pipe to each, and the cement-grout poured from this floor had a head or pressure equal to thirteen feet.

The grout used was of clear Portland cement (Lion brand) mixed to a consistency of thick cream. The mixing-boxes were two in number, five feet long, four feet wide, and one foot deep, placed side by side, and each divided into two sections by a partition in the middle. Each side of the partition was a two and a half inch hole with a wooden plug. On the under side was fastened a galvanized iron funnel, which was set on the top of the pipe. The mixing of the grout in each section of the boxes was continuous, so that a steady stream was running into the pipe from the commencement of the work to the finish. The pouring was commenced upon a pipe at the extreme end of the well, and the thoroughness of the work was shown by the water gradually rising in each of the other pipes, and finally filling each with solid cement. Sixteen and a half barrels of cement were thus used; but I estimate about one and a half barrels as wasted in the several pipes and in the overflow. I therefore estimate that about fifteen barrels were actually injected. Further borings showed that the cement extended at least six or eight feet beyond any of the vent-pipes, and how much farther it may have extended I have no means of knowing.

The work upon the foundations of the large pumps showed that the walls of the pump-well were badly cracked and broken by the various settlements. It was decided to grade up the bottom so that it would pitch toward the gate to lay a four-inch brick invert in the bottom, to line each wall with eight inches of brick-work, and to construct three additional cross-walls—one twenty inches thick and two twelve inches thick, one on each side of the suction-pipe. About nine inches of concrete were required at the north end of the well, running to nothing in the centre, in order to bring the bottom to a level. In order to obtain sufficient depth of water under the foot-valve of the large pump, the south half of the well was shaped up with concrete instead of brick. It



PUMP WELL,
Showing Method of Injecting
Cement Grout.

was intended to calk all of the leaks in the old wall before laying the brick-work ; but the old wall was found to be so weak and rotten that the calking of a large leak would cause a large number of small ones to burst forth. For this reason the calking was abandoned, and chasings cut in the wall to carry the water away from the new work as much as possible. In order to insure the new walls being perfectly water tight, the face course was kept about one foot higher than the backing-up course. The back of the face-course was well plastered and allowed to become solid and well set before laying the backing-up course, which was one-half a course below the face-course, thus making a complete break between the joints of the two walls. Holes were left in the work for the escape of the water, and when the work was complete these were calked with a putty made of hot grease and Portland cement, which set very hard the moment water struck it ; where necessary, oakum was calked with the putty. Portland cement was used in all the concrete, in laying the brick invert, the lower part of the walls, the three courses in the arches of the cross-walls, the tying-in of the cross-walls, and the whole north half of the well up to the top. The remainder of the work was laid in Rosendale cement. A large amount of cement was used dry in stanching water in the work, and almost all the mortar was one to one of sand. In the northwest corner of the well the largest leak was allowed to run through a pipe until all the work was completed, when the pipe was capped. The well was made perfectly tight, and no leaks have since been discovered.

SOME NEW SEWER FORMULÆ.

By R. Frank Hartford, Member of the Western Society of Engineers.

[Read March 3, 1885.]

The following formulæ are respectfully submitted to the profession, with the wish that they may prove to be as useful to others as they have been to the writer.

The two best-known formulæ for determining the flow of water in open channels are those of Weisbach and of Kutter, but both of these have proved inapplicable to brick sewers as ordinarily constructed, actual tests showing that the first gives results much too small, while the second gives results quite as much too large, with $n = .013$. If n be taken at .014, Kutter's formula gives good results ; but engineers hesitate in adopting it because of its cumbersomeness.

In my own practice I have used for several years, with satisfactory results, the following :

$$(1.) \qquad v = \frac{\left(m + \frac{0.00253}{S}\right) R \sqrt{S}}{\sqrt{R} + n\left(1 + \frac{0.000052}{S}\right)}$$

in which

v = mean velocity in feet per second ;
S = sine of inclination of flow ;
R = hydraulic mean depth.

m and n are constants, depending on the kind of channel bed, having the following values :

For brick, first-class work, $m = 184.07$, $n = 0.58$.
" " average " " $= 175.66$, " $= 0.65$.
" clay-pipe, well laid, " $= 225.7$, " $= 0.44$.
" " average, " $= 210.2$, " $= 0.50$.

As this formula is general in its application values of m and n for other material might be given; but the above suffice my present purpose.

For falls less than 1 foot in 2,000 feet, the following modification of (1.) is preferred, viz.:

(2.) $$v = \frac{m R \sqrt{S}}{\sqrt{R} + n}.$$

If Q = cubic feet discharged per second,
a = cross sectional area of flow.

(3.) $$Q = \frac{a m R \sqrt{S}}{\sqrt{R} + n}.$$

In a circular sewer, flowing full or part full, $a R$ may be represented by $x D^3$ and R by $y D$, x and y being coefficients, dependent on depth of flow, and D being diameter of sewer; so (3.) may be written as

(4.) $$Q = \frac{m x D^3 \sqrt{S}}{\sqrt{y D} + n}.$$

From the well-known Burkli-Zeigler formula for storm-water flow,

(5.) $$Q = c b (A^3 F)^{\frac{1}{4}},$$

in which c is a coefficient for drainage surface, b is coefficient for rainfall, A is drainage area in acres, and F is average slope of surface of ground per 1,000 feet.

Placing

$$\frac{m x D^3 \sqrt{S}}{\sqrt{y D} + n} = c b (A^3 F)^{\frac{1}{4}};$$

and equating for D, we have

(6.) $$D = \left(\frac{c b (\sqrt{y D} + n)(A^3 F)^{\frac{1}{4}}}{m x \sqrt{S}}\right)^{\frac{1}{3}}$$

Now let

q represent $c^{\frac{1}{3}}$
k " $b^{\frac{1}{3}}$
a " $\left(\frac{\sqrt{y D} + n}{m x}\right)^{\frac{1}{3}}$
N " $\frac{1}{S}$

and (6.) takes the following as a good working form :

(7). $D = a q k (A^{1.5} F^{0.5} N)^{\frac{1}{6}}$

The values of q and k are as follows :

$q =$
1.00 for roofs:
.88 " paved streets;
.69 " unpaved streets and lawns;
.67 " cultivated land, gentle slopes;
.85 " average city condition.

$k =$

.79	for	$\frac{1}{2}$	inch	rainfall	per hour.
1.00	"	1	"	"	"
1.08	"	$1\frac{1}{4}$	"	"	"
1.15	"	$1\frac{1}{2}$	"	"	"
1.21	"	$1\frac{3}{4}$	"	"	"
1.26	"	2	"	"	"

It will be seen that a is a variable, changing with the sixth root of D; but satisfactory results are obtained by the use of a constant (a), given below, and found as follows: For brickwork as commonly done in sewers, $m = 175.66$ and $n = 0.65$. For sewers flowing three-fourths full $x = 0.3017 \times 0.6319$ and $y = 0.3017$, whence

$$a = \left(\frac{\sqrt{0.3017\ D} + 0.65}{175.66 \times 0.3017 \times 0.6319}\right)^{\frac{1}{3}} \quad \text{or}$$

(8.) $a = 0.29331 \left(\sqrt{D} + 1\right)^{\frac{1}{3}}$.

By inserting an average value of D in (8.), we have as working constants,

$a =$

0.385	for brick,	circular,	good work	three fourths	full.
0.411	"	"	average	"	"
0.297	" clay	"	"	"	"

To these we may add

$a = 0.187$ for brick, oval, average work, two-thirds full for use in

(9.) $r = a\, q\, k \left(A^{1.5}\, F^{0.5}\, N\right)^{\frac{1}{6}}$

in which r is one half transverse diameter of an oval sewer whose vertical diameter is $\frac{3}{2}$ the transverse diameter.

These values of a will not err more than 4 per cent in extreme cases, giving results a trifle large in the smaller diameters and a trifle small in the larger diameters. Of course, any degree of accuracy may be obtained by substitutions and repetitions in (8.) and (7.) and (9.).

If the quantity (Q) to be discharged be known—

(10). D or $r = a \left(Q^2\, N\right)^{\frac{1}{6}}$

A comparison of formula (7,) with those in common use, may be of interest.

Let $A = 1000$ acres.

$N = 500$ feet.

$F = 4$ feet per 1000 feet.

Rainfall is one inch per hour.

For convenience the common formulæ are reduced to a similar form.

$$\text{Adams,} \quad \left(\frac{A^2 N}{6168}\right)^{\frac{1}{6}} = D = 6.58 \text{ feet.}$$

$$\text{Hawksly,} \quad \left(\frac{A^3 N}{9813}\right)^{\frac{1}{10}} = D = 5.89 \text{ feet.}$$

$$\text{Roe,} \quad \left(\frac{A^2 N}{5804}\right)^{\frac{1}{6.4}} = D = 5.90 \text{ feet}$$

$$\text{Prony,} \quad \left(\frac{A_2 N}{5804}\right)^{\frac{1}{5}} = D = 9.71 \text{ feet.}$$

$$\text{Downing,} \quad \left(\frac{A^2 N}{6168}\right)^{\frac{1}{5}} = D = 9.59 \text{ feet.}$$

The new formula gives for "average city condition," flowing full,

$$0.33\,(A^{1.5} F^{0.5} N)^{\frac{1}{6}} = D = 5.88 \text{ feet.}$$

STREET PAVEMENTS IN ST. LOUIS.

By Thos. H. Mackland, Member of the Engineers' Club of St. Louis.

[Read February 18, 1885.]

The first settlement of a country, or city, is always of interest in considering its subsequent growth and development.

One hundred and twenty-one years ago, on the fifteenth day of February, 1764, about three o'clock in the afternoon, Pierre Liguest de Laclede, August Chouteau, and others, came up the river in boats from Carondelet and below, and landing on the river front, at or near the present location of Market and Walnut streets, commenced cutting down trees and building a trading house on the present site of St. Louis. In this simple manner was the foundation of the great city laid; no blare of trumpets, no roll of drums, only the echo of keen axes swung by strong-armed men ushered in the natal day of the now great city by the great river. The lone trading post turned out to be a profitable venture, and a village gradually grew up around it, until St. Louis became a point of note on the Mississippi River, and on the general map of the country. After a lapse of forty-five years, the town of St. Louis was incorporated Nov. 9th, 1809, by the Court of Common Pleas for the District of St. Louis, under the authority of an act of the Legislature of the Territory of Louisiana, passed June 8th, 1808. At this period of her history the streets, and the public highways leading out into the country beyond, were of the most primitive kind, improved from time to time as the increase of business demanded; and as horses or oxen were not then, as now, expected to draw double their weight in addition to the vehicle, they in a measure answered their purpose.

In 1815 the first dray was introduced for transporting goods. The legend tells us that the driver thereof was one Patrick Laughlin. Be that as it may, it marked an era in street history of the city.

It was not an unusual spectacle during wet weather to see loaded drays, wagons and other vehicles. in the language of the day, "mired down" for hours, until finally released by the aid of additional oxen or horses, supplemented in extreme bad cases by levers in the shape of strong fence rails, which in those days of Arcadian simplicity were kept on hand by the provident trader to facilitate the onward march of traffic, so that by a combination of hard pulling, science, and perhaps, under the circumstances, justifiable swearing, the load sped on its way, as a shout of relief went up from the motley assembly who always congregate on such occasions. Thus street scenes were often displayed that, were they placed

on canvas, would be hailed as among the rare treasures of art, as illustrating the times and difficulty encountered by the trader in handling the limited commerce of the day.

The arrival of the first steamboat at the landing of St. Louis in 1818, presaged the future of the great valley, and gave a keener edge to trade; and it was not until about this time that anything of note in street improvement was attempted.

The lines of many of the streets were not definitely fixed until 1823, in which year a board of fifteen members was appointed, to ascertain and fix the boundaries and extent of the streets and alleys of the city, from oral and documentary evidence.

The charter of 1822 having authorized the levy of special taxes for paving and lighting streets, steps were taken by ordinance to commence the work in April, 1823. In August of the same year, an ordinance was passed to pave Main street in the best manner, with good strong stone, to be paid by special tax, excepting the intersections, which were to be paid for by the city, from the northeast, and west corners of the cross street leading to the ferry landing; to the northeast and west corners of the cross street which divided the lots of R. Wash and William Clark from the lots of Madame Benoist and James Loper." The ordinance of August 13th, 1823, also provided for streets, lanes and alleys, to be paved in the same manner as Main street with good strong stone.

St. Louis, and the country around about, being underlaid with limestone that material was naturally adopted, being easy of access; thus it came that the character of our streets was the natural outgrowth of our geological surroundings.

The general form of street and alley pavement was blocks, roughly dressed, irregular in size, from three to 12 inches thick, 6 to 14 inches long, and 6 to 10 inches depth, set on a sand bed 6 inches deep.

Alleys were paved then, as now, to drain on the centre line with a rise of one-half inch to one foot of cross-section; the streets were formed in general to carry off the water at the sides. The surface presented a moderately fair wheelway when new and while kept properly in repair, which, however, was rather the exception than the rule.

In 1823, an ordinance was passed to lay out a street along the river front, adopting the survey of the city made in that year as the true one, and that the map thereof be preserved. In this year a city surveyor was also appointed.

In 1824, Market street was widened to fifty feet, English measure, from the wharf to Fourth street. In 1826, the streets north of Market street, within the then city limits, received their present names; also streets running parallel with the river.

In 1827, July 27, an ordinance to grade, repair and clean the streets was passed, after a protracted discussion, over the Mayor's veto, so that in 1827 it was found that the growth of the city demanded clean as well as paved streets.

Prior to Sept. 24, 1828, the ferry landings had not been established. In that year an ordinance was passed fixing their location. In this year the office of Surveyor and Street Commissioner was consolidated, an important step towards a more uniform and continuous system of street service.

In 1829, Second street was ordered graded and paved, from Market street to Pine street, and Walnut street from Main street to the river; also in 1829, an ordinance was passed to grade Front street from Market street to Prune street, now Christy avenue, 37 feet 6 inches wide.

In February, 1832, an ordinance was passed to improve Second street, on the *macadamized plan*, from Spruce street to Almond street, with stone to be broken to pass through a 2 inch ring, the stone to be laid to a depth of 9 inches, the work to be paid for by special tax.

This was the first street improved in this manner. so that St. Louis has 53 years' experience with broken limestone, macadam, 67 years with limestone block pavements.

In 1840, we find the first inlet introduced to carry off the surface water at the corner of Laurel street, now Washington avenue, and Second street. The few sewers then in existence were built for private use ; no provision had as yet been made for house or street drainage ; but the question had begun to press itself on public attention. The accumulating flow of water during rains, over the street surfaces, as they were extended and improved, made it imperative, if good streets were to be maintained, that adequate under-drainage should be provided.

In 1841, Franklin avenue, from Fourth street to Seventh street, was graded and macadamized; this is the second mention of macadam since 1832. This year was also noted for the introduction of gas to light the streets, from Front to Seventh street and from Market street to Vine street.

From 1841 to 1842, street improvement was pushed with some vigor ; in the latter year, the wharf was ordered paved from Cherry street to Plum street, and for the first time the specifications for paving took a well-defined form : "The pavement to be laid with hard, solid stone, from the neighborhood of St. Louis, the paving sets to be 10 inches deep, 5 to 4 inches thick, and 7 to 12 inches long, placed on a bed of coarse gravel 7 inches deep, and then rammed with a rammer of the greatest weight the solidity of the stone would allow." The same general specifications for this character of work still prevail.

In December, 1841, the present system of sewerage was foreshadowed by ordinance No. 861, and has, since 1849, in general kept pace with and aided street construction in permitting better grades, the disuse of cross gutters, and the disposing of surface water to the great betterment of the streets, avenues, and alleys ; in fact, it cannot be said that a city can be well paved until properly drained.

Commercial street was first graded and paved, in 1842, with limestone blocks set on edge, and remained in stone until 1867, a period of twenty-five years, with repairs from time to time under the tonnage of that period, which may be put at 20 tons per foot of cross-section, the business being of a strictly receiving and shipping character, with little or no through traffic, which, on the basis of paving at the time, makes the cost of construction and maintenance one dollar and thirty cents per year per square of 100 feet superficial, during the period of twenty-five years. In 1867, this street was reconstructed with burnettized cottonwood, and again, in 1874, with white pine, *not prepared*, an average of seven years for each reconstruction, and costing an average of three dol-

lars and thirty cents per square of 100 feet superficial, exclusive of grading, preparing the foundation and repairs ; were the last item of expense at hand, it would still further enhance the cost. An examination of the first reconstruction, in 1872, showed the work badly affected with decay, having numerous holes ; an examination of the second reconstruction, in 1880, showed the pine to be in no better condition than the cottonwood that had preceded it, both having begun to show signs of weakness after three years, needing repairs early in the fourth year and constant nursing until the end; which had better occurred at the end of the fifth than the seventh year. for in fact the last years of the pavement had had no value, except by courtesy. Burnettized cottonwood and good white pine not Burnettized, for paving, may be rated as equal under the same conditions.

Walnut street from Main street to Second street was reconstructed with Nicolson pavement in 1860, the paving blocks were white oak, laid on pine flooring 1 inch thick with strips 3 inches high and 1 inch thick. the flooring tarred, the channels filled with dried gravel well rammed down, then poured full of a composition of gas coal tar; after four years and three months the street was repaired, and at the end of seven years had to be reconstructed. This was followed by a Nicolson pavement of cottonwood, which lasted six years; this again with a Nicolson of white pine, which lasted seven years; and after four years had to be repaired, and at the end of seven years was worn out, except a strip in the gutters; the three wood pavements averaging but six years and eight months; Walnut street is 36 feet wide between the curbs, with a grade of one and a half per cent., and a cross-grade of 0.04 to the foot; the traffic, about 70 tons to the foot of cross-section; the direction of the street being from east to west, which may be considered the most favorable one for a street to occupy with relation to light, heat and cold, which in the case of Commercial street, which runs north and south, no doubt had an effect, owing to its course, height of buildings, narrowness of street, and great amount of water thrown upon it from the house spouts during rains—decay in the blocks was materially accelerated, the street having succumbed from decay rather than from wear,

Stone block and macadam pavements constructed of limestone, from 1818 to 1860, had been thoroughly tried and found too short-lived, even when the material was carefully selected and the work well done, which in general was the case, the material being unequal to the wear thrown upon it by the growth and increase of traffic in the business centre of the city, to say nothing of the mud and dust; so that the introduction of wood on an extended scale in 1863 was a valuable one, when compared with limestone blocks and macadam, under heavy traffic.

The total Nicolson laid in St. Louis from 1860 to 1870 amounted to 16,651 squares, covering ten miles of contiguous streets in the business centre of the city, the original cost being $683,357, an average of $41.04 per square of 100 feet superficial, including the Nicolson patent fee : the average life of the pavement has been six years and three months ; for oak, cotton wood and rafted white pine, the cost of maintenance has been, in round numbers, $2.50 per square per year for the whole time, 19 years, on an average of 13,139 squares maintained for that period,

costing $470,630 ; total cost, $1,153,987, making the cost of 1 square for 19 years $87.82, and the cost of laying and maintaining 1 square per year, $4.62.

The highest price paid was $47 and the lowest $30 per square, except in the case of Walnut street, which cost $24 per square. The highest cost of maintenance was $4.16, and lowest $0.44 per square per annum. The flooring boards when taken up, at any time, were found to be but little affected by decay, and generally wore out two sets of blocks, being worn down to half an inch in thickness, in some instances, without being fractured after 10 to 14 years service, an indication of a good foundation, which in streets under consideration was in every case the natural grade, shaped to the desired form, with sufficient sand for leveling to receive the flooring ; it may be considered a mooted question if a plank floor is not as good, if not better, than a rigid foundation that is impervious to water ; when the blocks shrink, which they do either from a high or low temperature. Rains in summer and thaws in winter fill the open joints with water, which percolates through the joints in the flooring and in a measure escapes in the one case, and in the other case is held among the blocks until carried off by heat or dryness in summer, and in winter freezing and forcing the blocks out of position. To overcome this inherent quality in wood to shrink and swell, under the conditions of our climate, ranging from 15° below to 100° degrees above zero in the open air. These are points of vital importance and worthy of consideration in this connection.

Our experience with pine prepared under the creosote, or Thilmaney processes, gave no better results than the Burnettizing process; the blocks in the two cases mentioned were white pine. The elm blocks treated by the Thilmaney process take no higher rank than the others.

In 1880 sweet gum wood was introduced and put down at a number of points on the old Nicolson foundation.

On Main street, between Washington avenue and Vine street, in 1880, a block was put down of the above mentioned wood, prepared under the Wellhouse process, and after three years' wear, under a traffic of 150 tons per foot of wheelway, was badly broken up in 1884, and reconstructed in the same year with granite, thus costing the city an average of $5.33 per square of 100 superficial feet per annum, equal in round numbers to a yearly cost of 80 cents per front foot per year.

The grade on Main street from Washington avenue to Vine is 1.20 per cent., with a cross grade of 0.05 to the foot of cross-section.

Cherry street from the wharf to First street, put down in 1880, was totally worn out in the spring of 1882. This work cost $18.50 per square of 100 feet superficial. The grade on this block is 9 per cent., with a cross-grade of 0.04 to the foot of cross-section; the blocks were sweet gum prepared under the Wellhouse process, laid under the old Nicolson specification—the style of all our wood streets until 1884 ; the traffic on this block may be rated at 100 tons per foot of cross-section, 50 tons less than on Main street, the traffic on Main street being continuous, while that on Cherry street ebbs and flows, there being no through traffic, yet the grade of Cherry street being 7.80 per cent. in excess of that on Main street accounts for the greater wear under a much lighter tonnage ; yet

the cold fact remains that sweet gum paving blocks gave out in less than two years on this street, while cottonwood and white pine made a record of from 4 to 5 years under the same conditions; thus it will be seen that sweet gum has cost the city in round numbers on this block on Cherry street at the rate of $9.25 per square, equal to a ground rent per front foot of $1.40 in round numbers per year.

Main and Cherry streets at the points cited did not fail from decay, or defective workmanship, nor yet from wear—which did not exceed one and a quarter inches in three years on Main street, but from moisture, heat and cold, the gum wood blocks having shrunk and swelled to such an extent as to destroy the integrity of the pavement.

Much stress has been laid on bad foundations as being the prime cause of failure in our wood pavements, but there have been exceptional cases where the natural grade was of such an even character that the pavement wore out giving no sign of a deficient foundation.

In 1870, Olive street from Third to Fourth, and Third street from Olive to Locust, were reconstructed with Nicolson, Olive street in three sections, the west third of the block being paved with seasoned cottonwood, Burnettized, the centre third with rafted white pine not treated, and the east third of the block with cottonwood, green and wet, from the Burnettizing works.

The Third street block was the same as the east end of Olive street block. These two blocks lasted seven years, wearing out very evenly, the untreated pine and green, wet cottonwood wearing fully, if anything better than the seasoned cottonwood laid on the west end of the Olive street block, so that seven years was the life of the pavement fairly worn out, with only nominal repairs having been required. The tonnage on Third street at Olive, in 1875, was 180 tons per foot of cross-section grade, 1.50 per cent. on Third street, and 1.00 per cent. on Olive street, with a cross-grade of 0.04 to the foot of cross-section.

In 1870, a block of pavement was put down under the Stowe patent at the cost of the parties in interest, in full belief of success. White pine blocks and wedges were used without any preserving process on a carefully prepared sand foundation, flushed with water. The blocks were 3 inches thick and 6 inches high, with wedges 1 inch thick driven down between the rows of blocks until a channel three inches deep was left, which was filled with dry gravel rammed down and then poured with a hot composition of coal tar bitumen. This style of pavement was the child of many prayers, but after a brief life of 5 years dropped into an untimely grave, being taken with rot at the bottom of the block, and thus the theory of capillary action through the wood cells, giving a more uniform moisture and temperature relied on in this style of pavement to overcome decay, undue shrinkage and expansion, by thus placing the blocks directly on the sand foundation failed—the cure proving worse than the disease.

In 1884, Chestnut street was reconstructod from Jefferson avenue to Grand avenue with gum wood, on a base of hydraulic cement concrete 6 inches deep, laid on a steam rolled sub-grade. The base was, when finished to the grade, covered with a thin coat of number six coal tar pitch, upon which the blocks, 3 inches thick and 6 inches high, were placed at an

angle of 45 degrees with the centre line of the street, the rows being separated by a strip one-half inch thick, and one and a half inches wide, the channels poured with hot composition flush with the tops of the strips, and then filled with hot dry gravel rammed down and the channels again poured to fill the voids in the gravel. The blocks and strips are sweet gum. The lumber was subjected to a rigid inspection and all sap rejected; in fact, every precaution was taken in preparing the lumber for the treatment, which was with chloride of zinc, the impregnation such that any part of wood taken from a paving block when perfectly dry shall contain one part by weight of concentrated chloride of zinc, to 400 parts, by weight, of dry wood. On examination of this pavement, February 10th, 1885, the thermometer having marked 5 degrees below zero the previous night, it was found to be much opened at irregular distances, the cracks being from a well-marked line to one inch, and showing an aggregate shrinkage, from cold, of as much as 2 feet in a distance of 500 feet, equal .04 per cent. It remains to be seen, at a future time, what the effect of expansion will be, three per cent. having been as far as possible provided for.

Samples of Bois d'Arc put down, cobble badly, and in wet and freezing weather becomes dangerously slippery; cypress has shown no better record than four to seven years, the last three years a close struggle between life and death from decay.

All our wood pavements have exhibited one common defect, namely, their elasticity, which, were it only on the lines of the wood fibre, would do no harm, there being ample room in an upward direction, but this quality of shrinking from the cold or heat and expanding from moisture at right angles with the grain of the wood is a constant element of destruction, there being in theory and in fact no time in the life of a wood pavement when it can be called static, save at the moment it ceases to shrink and commences to expand. When this prime defect and all other defects have been overcome, the power of endurance, or ability to resist wear by the best known woods hitherto employed for the purpose, treated and otherwise, may be considered from 4 to 7 years with careful repair and cleaning, an important factor in street maintenance, with a traffic of 100 tons per foot of cross-section; this has been found the limit in St. Louis. The limit might be extended, in the absence of decay, by placing the blocks in juxtaposition, and the shrinkage was at the same time overcome, and the tendency to become loose from extreme cold, prolonged heat or dryness, and in damp or wet weather to expand, blister and bulge up from the foundation, by placing the blocks close; the wearing surface would be increased to the extent that the old system of strips and chanels was eliminated, but the expanding force would at the same time be correspondingly increased, the last defect being the worst of the two radical defects common to wood pavements—defects the remedy for which must be sought for in the treatment of the material before laid and in maintenance after being laid, by some yet unknown process that will protect the work from wet, excessive heat, dryness or low temperature.

ASPHALT PAVEMENTS.

In 1873 the first sample of asphalt block pavement was put down on a

sand foundation on Main street, between Walnut and Market streets, in front of the Merchants' Exchange. At that time, the life of the pavemen was estimated at at least 12 years by the parties who put it down. After a brief career of nine months it broke up and was replaced with Nicolson. The traffic on Main street in 1875 was 122 tons per foot of wheelway. In 1880, a block of asphalt block pavement was put down on Pine street, between Third and Fourth streets. After two years it was worn out and reconstructed with granite. The grade on this block is one per cent., with a cross-grade of 0.02 per foot of cross-section; traffic estimated at 100 tons per foot of wheelway. The foundation was bituminous concrete 6 inches deep and first-class in every particular. Again, in 1882, the same pavement, except as to the foundation, which was six inches of river sand, was laid on Locust street, between Leffingwell and Ewing avenues. The centre of the roadway gave out to such an extent that extensive repairs were found necessary in 1883. This street is in a residence neighborhood and traffic only nominal.

In 1883, the first sheet asphalt, the "American," "Grahamite," "Trinidad," was laid in St. Louis; two and a half miles of thirty-six foot carriage-way on Pine street, from Nineteenth street to Grand avenue, and on Locust street, from Seventeenth street to Compton avenue, laid on a base of hydraulic concrete six inches in depth. Upon this foundation there was spread what is denominated the cushion coat, half an inch in thickness, slightly richer in asphalt than the wearing surface, which is two inches in thickness and composed of sand and Trinidad asphalt, the general proportion being asphalt 12 to 15 parts, sand 83 to 70 parts, and pulverized carbonate of lime 5 to 15 parts. The work is to be maintained for a period of ten years, at a cost of one dollar per square of 100 feet superficial. The grades on this work vary from 0.80 to 2.50 per cent.; the cross-grade is 0.025 per foot of cross-section. In January of 1885 the traffic on Pine street averaged 2,200 vehicles in eleven hours, from 7 A. M. to 6 P. M., equal to 70 tons per foot of wheelway. Light repairs at a few points on Pine street were made in the spring of 1884. The cause of the defects is attributed to error in preparing the composition used at the points effected. The repairs were easily and quickly made. The work as a whole presents a fair surface after nearly two winters and one summer, under a temperature in 1883 of 19 and in 1885 of 5 degrees below to 100 above zero. Judging from the present condition of this work, there is reason to believe the pavement will prove satisfactory for traffic and well suited for sanitary reasons, if no other, to residence districts, being a non-absorbent.

STONE PAVEMENTS.

Porphyry block pavements were first introduced in St. Louis in 1869, and laid on Broadway at Howard street and Mound. The work cost $40 per square of 100 feet superficial. The traffic at this point in 1878 was 71 tons per foot of wheelway: the repairs have been but nominal, not to exceed 10 cents per square per year, or a total cost in 16 years of $41.60 per square, or $2.60 per square per annum. From the present appearance of the stones, they are good, with proper repairs, for 20 years more. The stone blocks in this work are irregular in dressing, from 4 to 6 inches thick, 6 to 10 inches long and 6 to 10 inches deep, set on 6 inches of river

sand, with a grade of 1.50 per cent. and a cross grade of .04 per foot of cross section.

Granite was introduced in 1873. Although the granite field of Southeast Missouri had been within reach since 1868 by rail, it was not until 1873 that any work of importance was undertaken, when Third street, from Biddle street to O'Fallon, was put down. In 1874, Third street, from Vine street to Morgan street, and Washington avenue, from Third street to Fifth street, was paved with granite from the "Knob Lick" quarries. This work is set on a 12-inch bed of clean river sand, the stone 4 to 6 inches thick, 6 to 12 inches long and 8 to 10 inches deep, set with a sand fed joint and rammed with a 90-pound rammer, the joints swept in, then flushed with water and rammed to a finished surface.

In 1879. the time had fully arrived when wood pavements no longer met the demands of the accumulating traffic of the city. The work done in 1873 and 1874 gave a key to the proper course to be pursued. In 1879, the work of reconstruction was commenced and pushed with unabated vigor, until at the close of the year 1884 2,166 squares have been laid, equal to 13.75 miles, the paving blocks since 1879 being dressed so as to approximate closely a rectangular form, three to four and a half inches wide, eight to twelve inches long and six to eight inches deep, the depth of foundation being governed by the character of the sub-grade.

The work on Third street, from Vine to Morgan street, has now been down ten years. This street takes the traffic of the St. Louis bridge, in addition to the through traffic of the street itself. The bridge traffic for 1884 was 428,758 1, 2, 3 and 4 horse vehicles of mixed character, and 61,697 1, 2, 3 and 4 horse coal wagons, being equal to a grand total of 490,455 vehicles, requiring to move them 1,056,278 horses, the traffic equaling 832,385 tons per annum, dis tributed on Third street from the bridge over the granite pavement before mixing with the Third street traffic proper. The traffic from the bridge equals 70 tons per foot of wheelway in 24 hours, to which add the Third street traffic proper and we have 270 gross tons per day per foot of cross-section. The granite pavement on Third street, at the bridge, as described, put down in 1874, on examination in 1885 was found to be in good condition, with but nominal repairs, although much disturbed by changing car tracks and other street openings, but may yet be relied on to double its record. This work has cost per square per year to date, including grading, five dollars per square. Wood at the same point would have cost fifty-four dollars per square, and been worn out, while the present pavement promises ten years of continued use.

St. Louis has tried many experiments in street construction since 1818, a period of 67 years, commencing with limestone blocks, then limestone macadam straight.

In 1851 and 1852, plank wheelways were tried, but failed to give satisfaction.

Limestone macadam, topped with gravel and rolled.
Limestone macadam, topped with sand and rolled.
Limestone macadam, topped with earth and rolled.
Limestone macadam, topped with Paducah gravel and rolled.
Limestone macadam, pitched with coal-tar-bitumen and rolled.

Porphyry macadam top-dressed and undressed.

Granite macadam straight and pitched with coal-tar-bitumen and rolled, so that the changes on macadam may be said to have been fully rung in St. Louis; but it is our geological neighbor and friend, as is the great river, and we can never be divorced.

In 1855, cobblestone was tried, but failed to give satisfaction.

In 1860, oak blocks on boards were introduced, and from 1863 to 1884, cottonwood plain, cottonwood burnettized, pine plain, pine burnettized, elm and sweet gum-treated flooring being used in every case except that of the Stowe patent, where the foundation was sand. In 1860, a number of blocks were put down with what was known as cellular iron pavement, which gave place to wood after eight years, being practically worn out and difficult to repair, besides being *exceeding slippery*, and on high grades, when worn, very dangerous. In 1868, the Fisk concrete claimed attention, and in 1869 it had succumbed to traffic after a 9 months' trial. Asphalt block has been tested and makes a handsome and desirable street, full of all the qualities that go to make a good wheelway except ability to stand the punishment of traffic.

Sheet asphalt was introduced in 1883, and gum wood in 1884 *on a concrete base*. Telford pavement has from an early date claimed deserved attention for outside streets, and top-dressed with gravel and rolled, makes a good road under a moderate traffic.

Select limestone blocks for alley work give fair service, except on alleys used for commercial purposes, where the use of granite would be economy. Of wood it may be said that while affording a pleasant and comparatively quiet street under traffic, with easy traction, it is unfit for business streets, being too short-lived and costly to maintain; still, it should be prefered to a macadam surface, where the macadam costs the same or even less to maintain, being cleaner, but it would be better economy to put down stone at once.

For residence streets or avenues the sheet asphalt takes a position that in view of its sanitary value, ease of repair, cleaning and pleasant wheel surface, cannot be overlooked as among the valuable road coverings of the day.

TREATMENT OF WOOD FOR STREET PAVEMENTS.

By Thos. J. Caldwell and Thos. D. Miller, Members Engineers' Club of St. Louis.

[Read March 4, 1885.]

The qualities of a perfect street pavement are about as follows: 1. Cheapness (of first cost); 2. Durability; 3. Firmness of foot-hold to horses; 4. Smoothness; 5. Noiselessness; 6. Elasticity; 7. Cleanliness; 8. Imperviousness to water; 9. Agreeableness of color.

"A pavement of wooden blocks possesses every quality of the perfect pavement, with two exceptions: It absorbs moisture to a considerable degree, and after a few years deteriorates very rapidly from decay. During this process of decay it offers less and less resistance to the wear of traffic, and finally reaches a condition in which it is unfit for travel, and dangerous to the public health.

"If this decay can be prevented the objection from moisture would not be serious and the wooden pavement would be preferable to almost any other pavement. and for almost every kind of traffic."*

The problem of preventing rot in wood gave rise to what is now known as

WOOD PRESERVING.

On account of the abundance of wood, it has always occupied a prominent position in all works pertaining to Engineering. This was particularly so in earlier times, and at the present it cuts a very prominent figure in every structure. The comparative ease and facility with which wood is handled, not to mention the many special advantages which it possesses over other materials in particular cases, and especially the advantage of first cost, have conduced to make its use even more extensive. The one great drawback has always been its short period of service, necessitating frequent renewals and repairs, and consequently increasing its ultimate cost. Wood is now used to such extent, that fears are entertained of the near approach of the time when the supply will be entirely inadequate to the demand. The fact has long since been recognized that in subjecting wood to some treatment previous to construction, its life may be considerably lengthened, and thus the ultimate cost reduced, so that in a particular case it is a matter of earnest consideration whether or not it possesses superior merits justifying its employment in preference to other materials. The result is that the business of wood-preserving has become a prominent one, but unlike many other industries, the progress of it has been very slow, principally from the reason that long time is necessary to prove the measure of its utility.

The favorable conditions for putrefaction are the presence of moisture and heat; these exist in a pavement the greater part of the time.

It has been proven by Pasteur, Tyndall and others, that "no putrefaction can occur in a nitrogenous substance if its bacteria be destroyed and new ones prevented from entering it. Putrefaction begins as soon as bacteria, even in the smallest numbers, are admitted, either accidentally or purposely. It progresses in direct proportion to the multiplication of the bacteria, it is retarded when they exhibit low vitality, and is stopped by all influences which either hinder their development or kill them. All bactericidal media are therefore antiseptic and disinfecting."†

If some process be found by which, first, the bacteria existing in the wood are killed; second, an antiseptic is introduced that will kill or prevent the development of such as may subsequently be deposited; and, third, the presence of the antiseptic is rendered permanent, we will have a perfect preventive of wood rot.

Tyndall says that some bacteria are killed by a momentary exposure to the temperature of boiling water, while others withstand it for several hours. If the wood be subjected to three or four hours' steaming at from 240° to 250° F., it will be safe to assume that all bacteria have been exterminated. This, however, is not the only benefit derived from steaming the wood. The pores are opened by the expansion due to the heat, and

* Report of Board of Public Improvements for the fiscal year ending April 8, 1878, p. 202

† Prof. Cohn, of Breslau.

the steam, condensing, washes out the sap to a greater or less extent, and coagulates largely what albumen remains.

Many antiseptics have been used and numerous experiments made to determine their efficiency. M. Jalan de la Croix experimented on the relative power of various antiseptics in preventing the development of bacteria of putrefaction. Finely divided boiled or raw meat was placed in water; one gramme of the antiseptic was used in all cases, and the figures in the table below give the number of grammes of the decoction in which the one gramme gave the indicated result :

TABLE OF THE RELATIVE POWER OF VARIOUS ANTISEPTICS.

Antiseptic	Maximum dose in which development is not arrested.	Minimum dose in which development is arrested.	*Antiseptic.*	Maximum dose in which development is not arrested.	Minimum dose in which development is arrested.
Alcohol	30	1.77	Ethereal Oil of Mustard	5,734	40.
Chloroform	134	1.	Sulphurous Acid	7,534	72.
Biborate of Soda	107	14.	Acetate of Alum	7,535	478.
Eucalyptol	308	14.	Salicyclic acid	7,677	343.
Phenol (carbolic acid)	1,002	10.	Bichloride of Mercury	8,358	2,525.
Thymol	2,229	20.	Hypochlorite of Lime	13,092	109.
Permanganate of Potash	3,041	35.	Sulphuric Acid	16,78[illegible]	135.
Picric Acid	7,041	100.	Iodine	20,020	401.
Borated Soda Salicycelate	3,377	30.	Bromine	20,875	493.
Benzoic Acid	4,020	50.	Chlorine	34,509	431.

Several of the above have been used for the preservation of wood. In this connection should be mentioned compounds of zinc, lead, copper, iron, arsenic, lime and creosote oil.

The action of the aqueous solution of the metal salts is to coagulate the albumen of the sap, besides its action as an antiseptic. The action of creosote oil is the same, while it fills the pores of the wood with a bituminous asphaltic substance which gives a waterproof coating to the fiber, preventing the absorption of moisture.

The following abstracts give a brief history of wood preserving :

1737. Mr. Emerson patented a process which consisted in saturating timber with boiled oil mixed with poisonous substances. This is believed to be the first patent on a process for preserving wood.

1740. Mr. Reid proposed to arrest decay of wood by means of a certain vegetable acid.

1756. Dr. Hales recommended that the planks at the water-line of ships should be soaked in linseed oil.

1758. Du Hamel and Buffon experimented on a process for preserving wood, but with no satisfactory results.

1769. Mr. Jackson proposed the use of salt water, lime and potash salts.

1773. From 1768 to this date the practice of saturating ship timbers with a solution of common salt prevailed.

1779 Mr. Pallas, in Russia, proposed to steep wood in a solution of sulphate of iron and then in a solution of lime to precipitate the vitriol.

1784. M. Megueron worked on a process for preventing decay.

1796. Hales proposed to creosote the treenails of ships. This was 42 years prior to Bethell's patent for creosoting.

1805. Mr. Maconochie proposed to saturate inferior woods with resinous and oily matters.

1811. Cadet de Gassicourt tried mineral substances and unguents.

1813. M. Champy suggested a bath of hot tallow.

1815. Mr. Wade proposed a caustic alkali solution of common resin. Soaked the timber in the solution, and afterward plunged it into acidulated water. He also recommended solutions of sulphates of copper, zinc and iron. Mr. Boyden boiled the timber in lime water and then in a thin solution of glue.

1817. Mr. Chapman recommended sulphate of copper and bichloride of mercury.

1822. Mr. Oxford patented a process which consisted in saturating oil of tar with chlorine gas and mixing with it finely ground carbon of purified coal tar, oxide of lead and carbonate of calcium, and applying the composition in thick coatings.

1832. Mr. Kyan patented his process of treating with bichloride of mercury which has met with considerable success. Closed vessels and high pressure were first used in charging the timber in this process.

It was proposed in America to apply pyroligneous acid to the surface of wood or to introduce it by fumigation.

1835. Franz Moll, a German, proposed the use of creosote in a state of vapor, but it was attended with great expense.

1837. Boucherie's process of impregnating with copper sulphate was very successful and was extensively used.

Mr. Flockton used wood tar and acetate of iron. This is thought to have been a failure.

1838. From 1831 to 1838 Bréant operated in France with a mixture of linseed oil and resin. In 1838 he patented the method of impregnating by atmospheric pressure.

Mr. Bethell patented his process of creosoting. It was suggested to him by his observations on mummies. The process found great favor, and was extensively used in England, Scotland, Ireland, Belgium, Holland, France, Prussia, India and America.

1840. Between 1838 and 1840, Sir William Burnett introduced his process of treating with zinc chloride, impregnating under pressure as high as 150 lbs. per square inch.

1846. The Burnettizing process was carried from England to Bremen, and by 1851 had spread over Germany and Austria.

As the above chronology shows, a great number of methods have been used; but few, however, have proven successful. At least three, when well executed, can be relied upon to prolong the life of wood. These are, essentially, Kyanizing, Creosoting and Burnettizing, and are too well known to warrant a minute account of them here.*

Kyanizing.

Mr. J. B. Francis says: "I have specimens of cottonwood, kyanized nearly twenty years ago, which have been in the ground ever since, and are still sound, the wood retaining its strength and color, while other specimens, not treated, and under the same exposure, have so completely decayed as to become nothing but black mould."†

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* See Trans. Amer. Soc of Civ Engrs., 1882; Proceedings of Engrs.' Club of Philadelphia, Vol. 1, 1880; Proc. Inst. Civ. Engrs. Vol. 78.
† Trans. Amer. Soc. C. E., 1882.

And as will be seen. from the table of experiments by M. de la Croix, bichloride of mercury possesses more than five times the antiseptic powers of any of the other substances determined. However, this process seems to have fallen into disuse, and, so far as we can learn, has never been used in paving blocks to any extent.

Creosoting

consists in impregnating the wood with dead oil *

"Numerous instances of pavements laid with blocks preserved by this process may be found in our cities, which have remained sound for many years, but there are also instances where timber impregnated with creosote has failed to give satisfaction. The fault in such cases may be assumed to be either in incomplete impregnation or in the poor quality of the material used. Full impregnation can easily be secured by thorough supervision and inspection of the work, but it is very difficult to secure the proper material, not only for the reason that the original chemical constituents of the tars, from which the heavy oil of tar (generally called creosote) is gained by distillation, differ very much, but because the final product for preserving purposes depends greatly on the extent to which distillation has been carried. If the proper proportion of ingredients in a good creosote could be stated with exactness, and if chemical analysis could readily determine the quantity of the various ingredients present in a creosoting fluid proposed to be used, complete success of the process could be assured in all cases. But as neither of these conditions can be readily filled, certainty of success cannot be warranted, as it can in the case of impregnation with metal salts, except under a system of the most rigid and expensive supervision."†

Burnettizing

consists in injecting into the timber a solution of chloride of zinc ($Zn\ Cl_2$).

Mr. J. W. Hobart, in a letter written April, 1882, to Mr. O. Chanute, says "an old side track was removed which had not been in use for several years, and which was nearly covered with earth and grass, still the hemlock ties were then found nearly sound, having laid there for nearly 25 years. * * * There is no doubt that the preservation of these ties was due to this process."‡

There is abundant evidence of the efficiency of chloride of zinc as a preservative. It has passed from the field of experiment and become an established fact.

In earlier times the manner of impregnating the wood was by soaking, but this was not found to be effective within a short period. Therefore, closed tanks and pressure were introduced, which is the practice to-day.

The methods employed for incorporating the antiseptic may be divided into two classes, viz.: the direct and the indirect. In the direct method the wood is subjected to the action of a single solution, which may be either simple or compound. In the indirect method the wood is subjected to the action of two solutions, one following the other, both or either of which may be simple or compound. By the direct method the antiseptic is introduced bodily into the wood in the solution. By the

* See Proceedings of Engineers' Club of Philadelphia, Vol. 1.
† Report of Board of Public Improvements for fiscal year ending April 11, 1881.
‡ Trans. Amer. Soc. Civ Engrs., 1882.

indirect method the antiseptic may or may not be introduced at once in the first solution, and the second solution may be for a single or a double purpose; for a single purpose when the idea is to effect such a transformation as will tend to fasten the antiseptic which has already been introduced; for a double purpose when the idea is to effect such transformation as will not only tend to fasten the antiseptic, but also simultaneously the antiseptic itself is the outcome of the transformation. As illustration of the direct method, take the simple Burnettizing process. As illustration of the indirect method, take the zinc-thilmany process, where the first solution is the sulphate of zinc ($Zn\ SO_4$), and the second solution chloride of barium ($Ba\ Cl_2$). The introduction of the latter solution is based on the idea that such transformations are effected as will not only form the antiseptic zinc chloride, but also that the antiseptic may be preserved intact by the fixing action of the barium sulphate ($Ba\ SO_4$), which is one of the results of the transformation.

In this city there are two Wood-Preserving Companies: The St. Louis Wood-Preserving Company, and The American Wood-Preserving Company. The former company use the zinc-tannin process, and the latter company use the zinc-gypsum process and creosoting process.

In the year 1880, the St. Louis Wood Preserving Company erected additional appliances at their works, and were engaged by the city to treat material for street pavements by the zinc-thilmany process. The following were the specifications in the contract, viz.:

1. Steam the blocks 3 hours at from 15 to 18 lbs. pressure (not to exceed 240°).
2. Apply vacuum 20 minutes at 5 lbs. pressure.
3. Apply $Zn\ SO_4$ solution 2 hours at 80 lbs. pressure (1st injection).
4. Apply vacuum 5 minutes at ½ lb.
5. Apply $Ba\ Cl_2$ solution 2½ hours at 80 lbs. (2d injection).
6. One half of one per cent. of $Zn\ Cl_2$ to remain in every part of the blocks. On the assumption that the average weight per cubic foot of gum wood was 40 lbs., and that it absorbed 30 per cent. of its volume of the first solution, and on the supposition that the two solutions exactly neutralize each other bulk for bulk, each occupying one-half of the absorption, it was found that to realize this one-half of one per cent. of $Zn\ Cl_2$, the $Zn\ SO_4$ solution should be 2½ per cent. strength and the $Ba\ Cl_2$ solution should be 3.2 per cent. strength. In the operation of the process it was observed after steaming the wood that ⅓ of the first solution penetrated the wood immediately upon being let into the cylinder, and the remaining ⅔ required the hydrostatic pressure. It was also noted that only $\frac{1}{6}$ as much of the second solution as of the first could be forced into the wood, or, in other words, the wood was surcharged with the first solution and the transformations consequently effected were far short of the requirements. The average results obtained by this treatment in five gum blocks were as follows:

Average ½-inch from end of block	—	.21	per cent.	$Zn\ Cl_2$.
" 1 " "	"	— .04	"	"
Centre	"	— .30	"	$Zn\ SO_4$.

On one occasion the second solution remained 30 hours in contact with

the wood under a set pressure, and the results obtained showed a large increase, viz.:

Average $\frac{1}{2}$ inch from end of block — .89 per cent. $Zn\ Cl_2$.

Centre of block — .48 per cent. $Zn\ SO_4$.

After these blocks dried out the precipitated barium sulphate was found to vary on the opposite ends of the same block, and that there was a wide difference in the quantity the several blocks received, although apparently under the same conditions.

On opening the cylinder the blocks were found to be heavily coated with barium sulphate, and it is more than probable that the instantaneous transformation to the precipitate barium sulphate on the fibre ends of the blocks so filled up the pores that a slight reaction was all that could be effected further in the blocks. Long contact with the second solution gave better results, but in operating any process the long contact necessarily adds greatly to the cost, and consequently precludes its practical use. Were it practicable to give the blocks as much of the second solution as of the first, the expected results would be realized.

The Zinc–Tannin

process consists of a solution of $Zn\ Cl_2$ and gelatine for the first solution, and the second a solution of tannic acid. Chemically considered, gelatine is precipitated by tannic acid and forms leather, the idea being that this formation of leather in the pores of the wood protects the $Zn\ Cl_2$, the presence of which is already assured.

The following analyses were made of blocks treated by the zinc-tannin process, and show to some extent how successful this method is:

Description.	No.	Time in Pavement.	Part of Block Analyzed.	Per cent. $Zn\ Cl_2$.
5 in. gum block	a	2 years	Centre	$\frac{44}{100}$
" " "	b	3 "	"	$\frac{21}{100}$
" " "	c	3 "	"	$\frac{15}{100}$
" " "	d	3 "	"	$\frac{25}{100}$
" " "	a	2 "	Top	$\frac{80}{100}$
" " "	a	2 "	Bottom	$\frac{51}{100}$
" " "	b	3 "	Bet. 1 in. and $\frac{1}{2}$ in. from bottom	$\frac{28}{100}$
" " "	c	3 "	" 1 " $\frac{1}{2}$ " "	$\frac{31}{100}$
" " "	d	3 "	" 1 " $\frac{1}{2}$ " "	$\frac{32}{100}$

These blocks were steamed for 3 or 4 hours at about 18 lbs. pressure, and the zinc chloride solution was applied for 3 or 4 hours at from 95 to 100 lbs. pressure, and then the tannin solution was applied for 2 or 3 hours at from 95 to 100 lbs. pressure.

The Zinc-Gypsum

process consists of a single solution of zinc chloride and gypsum ($Ca\ SO_4$) injected into the wood. Gypsum is soluble in a solution of zinc chloride, and it is claimed that when the wood becomes dry the gypsum crystallizes out and thus protects the zinc chloride which has accompanied it.

It is impossible to state how effective this method of fixing the antiseptic in the wood is, because no work done by this process has been down for a length of time sufficient to determine even partially as to the validity of the claim, the only true guide being actual service. Experiments made by us show that gypsum is readily dissolved by a zinc chloride solution, which, on being allowed to evaporate to dryness, leaves a

residue of zinc chloride and crystals of gypsum, all of which re-dissolves upon the addition of water. We are therefore inclined to the opinion that, as the double solution can not deposit more gypsum in the wood than the zinc chloride solution carries there, the introduction of water into the dry-treated wood will re-dissolve the zinc chloride, which in turn takes up the gypsum as effectively, perhaps not so rapidly, as it would the zinc chloride alone.

During the process of steaming wood the pressure should never be allowed to rise above 15–18 lbs. per square inch, as beyond that point the temperature is such as to become injurious to the wood. The following table gives the corresponding degrees Fahrenheit for pounds pressure steam :

Temperature of steam Fahr (T.).....	Pressure in lbs. per sq. inch (P.).....	Difference of pressure for 1° temperature (D. P.)........	T.	P.	D. P.	T	P.	D. P.
					.419			.599
212	0 00		235	8 12		260	20.80	
		.294			.426			.6 7
		.304			.452			.642
215	.90		240	10.30		265	23.92	
		.310			.458			.651
		.330			.485			.687
220	2.50		245	12.65		270	27.26	
		.335			.492			.696
		.358			.520			.733
225	4.23		250	15.18		275	30.83	
		.364			.527			.743
		.388			.559			.780
230	6.10		255	17.89		280	34.63	
		.394			.567			790

The pressure necessary with a 2 per cent. solution to impregnate a 5 or 6-inch gum block, leaving $\frac{25}{100}$ per cent. zinc chloride in the centre, within a limited time (say 4 hours), is little less than 100 pounds per square inch. Experiments made by Mr. J. P. Card, President of the St. Louis Wood-Preserving Co., show that steamed wood takes solution readily without pressure, to a limited extent, then it absorbs it very slowly, and, if 10 pounds pressure be applied, it again takes solution rapidly to a certain point, when it almost stops ; and so on, with a decreasing scale, up to 100 pounds, beyond which it is very stubborn, pressure or no pressure. With a pressure of 100 pounds and a 2 per cent. solution, more than $\frac{25}{100}$ per cent. of zinc chloride can be injected into every part of a 5 or 6-inch paving block inside of four hours. This conclusion is supported by the results of analyses made by us. Six-inch gum blocks treated with a maximum pressure of 40 pounds for four hours show, from nineteen analyses of their centres taken across the fibre, an average of $\frac{7}{100}$ per cent. zinc chloride. The number of blocks for each analysis ranged from one to four, the highest result being $\frac{18}{100}$ per cent., the lowest $\frac{3}{100}$ per

cent. Five-inch gum blocks treated with a maximum pressure of 100 pounds for 3½ or 4 hours show from seven analyses of their centres, taken across the fibre, an average of $\frac{36}{100}$ per cent. zinc chloride. The number of blocks for each analysis ranged from one to six, the highest result being $\frac{57}{100}$ per cent. zinc chloride, the lowest $\frac{28}{100}$ per cent. zinc chloride. A 2 per cent. solution was used in all cases.

Frequently, with two or more charges treated in precisely the same way, with all conditions similar, the analyses gave different results, which can be accounted for in no other way than that the difference in the structure of the wood examined was the cause.

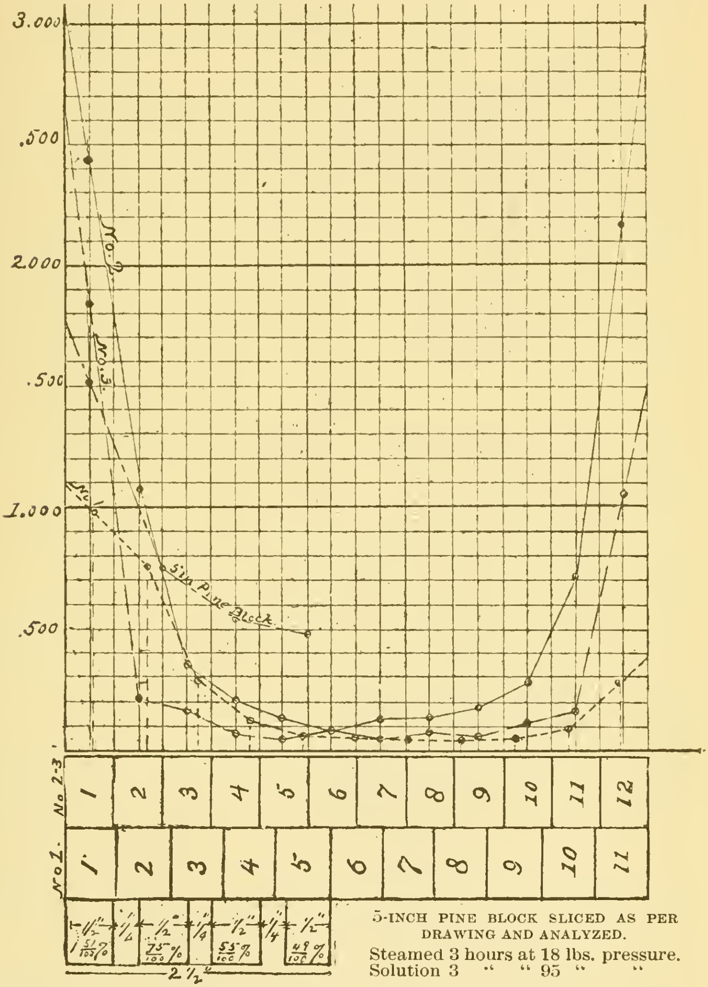
In order to determine how nearly uniform the zinc chloride was distributed through the blocks, three examinations of 6-inch gum blocks were made. Sliced block No. 1, a white gum, was cut across fibre into 11 equal slices and each slice analyzed. Sliced block No. 2, a white gum, was cut into 12 equal slices, across fibre, immediately on coming from the cylinder, and each slice analyzed. Sliced block No. 3, a red gum, to all appearance a duplicate of No. 2, and treated in the same charge, after coming from the cylinder was placed with its fibres horizontal and allowed to thoroughly dry, when it was cut and analyzed in the same manner as No. 2. The results are as follows, which, for the sake of comparison, have been platted, taking the horizontal line for the scale of slices and the vertical line for the scale of per cents. These blocks were treated by the zinc-gypsum process in the summer of 1884, at the time the blocks for the Chestnut street pavement laid in this city in that year were treated. They were steamed 6½ hours, at 30 lbs. pressure, and were in a 2 per cent. solution 12 hours, at 40 lbs. pressure.

No. Slice.	Block No. 1. per cent. $ZnCl_2$.	Block No. 2, per cent. $ZnCl_2$.	Block No. 3, per ct. $ZnCl_2$.
1	.989	2.440	1.842
2	.776	1.086	.212
3 ...	.293	.352	.163
4... ...	.118	.209	.062
5	.067	.133	.045
6	.054	.080	.084
7.	.045	.131	.057
8	.056	.134	.074
9... ...	.072	.183	.064
10..	.092	.285	.107
11.......	.295	.720	.158
12 ...	....	2.174	1.653
Average.	.260	.661	.377

Examinations of s. b. No. 2 and No. 3 were made for the purpose of determining to what extent, if any, the zinc chloride became diffused through the block while it was drying. Notwithstanding the two blocks were of different kinds of gum, there is no evidence that diffusion takes place to any extent, but would seem to indicate that the solution exudes somewhat. The average of s. b. No. 2 lies between the second and third slices from either end; of s. b. No. 3 the average lies between slices Nos. 1 and 2, and 11 and 12. Assuming the impregnation to have been equal, there has resulted a shifting of the average during the drying as much as ½ inch from the centre toward either end. Slices 4 to 9 of s. b. No. 3, when compared with those of s. b. No. 2, apparently show that there has been some equalization in the block while drying.

It will be observed that the curves are considerably higher on one side than on the other, which shows that the solution enters more freely from one end than from the other. This result is due to the valves of the sap vessels. The solution, entering from the tree-top end of the block, meets with resistance from these valves, while, from the other

end, the valves are acting as in the natural tree and offer no resistance, but may facilitate the absorption and prevent the exudation at this end when the pressure is removed. It is an established fact that posts set tree-top end down last much longer than when in the natural position. This phenomenon is also due to the action of the valves of the sap vessels. In the post set in its natural position the valves act so as to hold what moisture may be drawn into the wood by capillary attraction and thus



5-INCH PINE BLOCK SLICED AS PER DRAWING AND ANALYZED.
Steamed 3 hours at 18 lbs. pressure.
Solution 3 " " 95 " "

facilitate decay, while in the post reversed the action of the valves is to resist the entrance of moisture. Now, in a wood pavement with a water-tight concrete foundation the moisture comes from above, and it seems, could inspection be carried to this extent, that the life of the wood would be lengthened were the blocks placed in the pavement tree-top end up. The blocks would, at least, then be in a position to best resist the dissolving action of water in carrying off the antiseptic.

Various kinds of wood differ very materially as to their power of taking solution. Analyses made of a sample taken from the centres of six 5-in. pine blocks, and of a sample taken from centres of six 5-in. gum blocks treated at the same time show for

$$\text{Pine, weight per cubic foot 25.7 lbs. } \frac{60}{100} \text{ per cent. } Zn\,Cl_2.$$

$$\text{Gum, " " " 32.0 " } \frac{38}{100} \text{ " "}$$

or the impregnation of pine is to gum as 100 to 62 when estimated by per cent. These blocks were treated with zinc chloride, steamed 4 hours as 18 lbs. pressure; in solution, 3 hours at 100 lbs. pressure.*

It will be observed that the average weight per cubic foot of the pine blocks was only 25.7 lbs. and that of the gum blocks was 32.0 lbs. Where the pine showed $\frac{60}{100}$ per cent. $Zn\,Cl_2$ the gum showed only $\frac{38}{100}$ per cent. $Zn\,Cl_2$, whereas if the gum had taken $\frac{48}{100}$ per cent. it would have contained actually as much of the antiseptic as the pine, or if the pine had taken only $\frac{47}{100}$ per cent. $Zn\,Cl_2$, it would then have contained actually at much as the gum with $\frac{38}{100}$ per cent. The conclusion is therefore obvious, that where the quantity of the material to be incorporated is specified by the per centum, the weight per cubic foot of the wood should be considered.

Inspection.

The inspection of paving blocks should be made before treatment, because after treatment the blocks are found to be so discolored as to defy the detection of bad ones.

Chemical analyses should be made, at intervals, of the solution used, as the hydrometer test can not be relied upon for an indefinite time.

In order to insure the success of the process, a chemical examination of a sample from each charge, or run, should be made.

All methods of preserving timber depend for their success upon the skillful and conscientious manner in which they are executed, for as they involve chemical action on a large scale, their efficiency must depend upon the observance of the minute practical precautions required to exclude disturbing causes.

Statistics can be adduced which prove conclusively that wood treated in a proper way is of the most decided economy; but, in view of the fact that the failures of treated wood pavements are traceable to improper or imperfect treatment, to bad foundations or to the physical properties of the wood used, treated wood for street pavements can as yet be considered as scarcely more than an experiment.

It will, of course, be conceded that a wood which will wear out before it begins to rot will in nowise be benefitted by treatment.

The first desideratum for a treated wood pavement is a wood which combines a maximum of wearing quality with a minimum of expansion and contraction, together with a minimum of cost. Such a wood, well treated and carefully laid on a proper foundation, would undoubtedly give decidedly economical results.

* We intended to present similar analyses of spruce, hemlock, oak, elm, cottonwood, and others, but through some misunderstanding the blocks were not treated in time for the analyses to be made.

HYDRAULIC ENGINEERING IN THE SOUDAN.

By Howard Constable, Member of the Engineers' Club of St. Louis.

[Read March 18, 1885.]

You may find it interesting at this time to have a brief account of the pipe line which the British Government has decided to construct in the Soudan.

The Mahdi has proved a stimulant to the profession, and it is ungratefully providing an anti-stimulant for him. The pipe line, or system of water works, is to supply water along the route between Suakim on the Red Sea and Berber on the Nile. This will enable Gen. Graham's army to make the journey across the desert country to join Lord Wolseley, and also enable the railway to be constructed between Suakim and Berber, which latter point Gen. Wolseley seems desirous of making a new base of operations.

The accompanying map of Egypt has drawn upon it the proposed alignment of pipe line and railway. The water route between Cairo and Berber is 1,200 miles, and by no means an easy or rapid line of communication, as we have all been made aware of, by the frequent accounts of Gen. Wolseley's progress up the Nile, extending over the past few months. The distance from Suakim to Berber, "as the crow flies," is about 245 miles, but the practical route for the railway is from 260 to 280 miles. The pipe line will probably be somewhat shorter than the railroad, as it need not be restricted by grades, and therefore can make some short cuts. The country is rough and broken, and nearly destitute of water, at least to the extent of the wells being very irregularly distributed, and the amount of the supply very meagre and uncertain; therefore a sufficient and steady supply of water must be had at any cost, if the attack on the Mahdi is to be made from Suakim this coming fall.

The War Office, after long consideration and consultation, sanctioned the plan of laying lines of pipe the whole distance and establishing pumping stations wherever necessary. There are to be two lines of 4-inch pipe two pumping engines at each station, the stations 15 to 30 miles apart, and each station will be made a military post. The distance between stations will vary considerably, according to the profile of the line and the best sites for military posts.

As stated, the profile of the country between Suakim and Berber is quite irregular. Berber is about 1,000 feet above the level of the Red Sea, and the intervening country has at least two summits of 2,500 to 3,000 feet to be crossed by the pipe line.

While oil has been pumped unbroken over 100 miles, a shorter distance is better adapted to making the best combination of the various conditions that must be considered, especially in this case: 1. Quantity of water required. 2. Size of pipes and facility with which they can be handled. 3. Relation of pressure to size of pumps and pipes. 4. Inspection and protection of the line. The pumping engines are direct-acting, of the Worthington duplex form, as seen in many of the water-works of

the country, excepting that the water end is of special design for heavy pressures, similar to those designed for the Standard Oil Company.

The resistance to be overcome by the pumps varies with the profile of the ground and the distance between stations. In amount it will be from 500 to 1,000 pounds per square inch, and the pumps are tested to a pressure of 2,000 pounds per square inch before leaving the works. Those that have been shipped have an 18-inch steam cylinder, 5-inch plungers, and 18-inch stroke. The plungers are outside packed. Valves are in detached chambers, which are rounded in form and as small as possible, as shown in the drawing. Though the valves are small, the total number afford very ample water passage. The water and steam ends are rigidly connected by rods, and are bolted to a cast-iron bed-plate. The space occupied by the pump is about 15 feet in length, and the amount of steam required will be about 150 to 200 horse-power.

The accompanying photographs and lithograph will give you a better idea of the construction and some of the details. The amount of water is 150 to 200 gallons per minute, which is equivalent to 216,000 to 288,000 gallons per day. At least one pump a week is to be shipped, and several have already gone, the Adriatic taking the first and the Britannic and Germanic following with the others.

The pipe will be of wrought iron, four inches in diameter, re-enforced ends, with long screw thread. It will be joined by long wrought-iron screw sleeves. It will be laid serpentine, to allow for expansion and contraction, and thus avoid special "slip" or "expansion joints," which are found unsatisfactory. The pipe will be buried, and any tampering with it, or the valves located along it, will immediately indicate itself at the pumping station by a reduction of the pressure; whereupon a gang of repairers with a military escort will proceed along the line. There will be two lines of pipe, with two pumps at each station; the pipes deliver into a tank from which the pumps draw the water and pass it along to the next station. The order for pipe will amount to about $750,000, and, it has been rumored, may possibly be placed in this country, as our English cousins have had little experience in this class of pipe, and are not quite so well prepared as our manufacturers with machinery for the special connections and to turn out the pipe rapidly. About 20 miles a day is required, the whole amount needed being about 520 miles.

While this pipe line for the Soudan is a novel war measure, the enginering part is not without precedent.

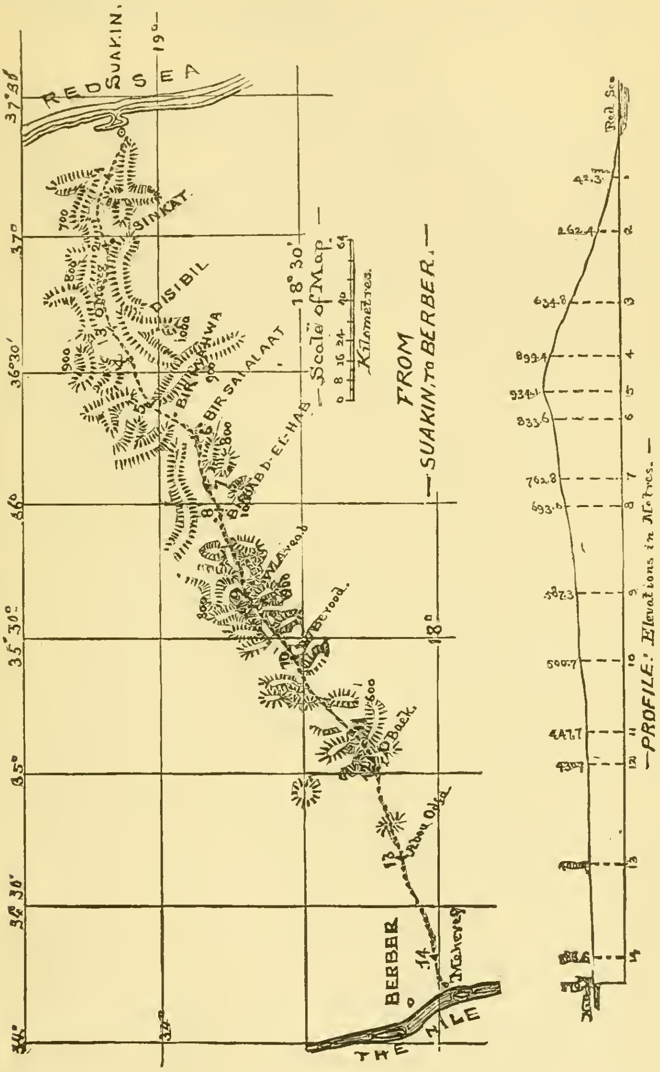
The accompanying maps illustrate how extensively pipe lines have been used in the oil regions. You will notice that from the oil belt northeast of Pittsburgh they radiate to New York, Philadelphia, Baltimore, Pittsburgh, Cleveland and Buffalo. The profile shows how they run over mountains and valleys.

At New York they cross the Hudson River 80 feet below the surface.

And in this city of St. Louis the Waters-Pierce Oil Company have two small lines some two miles in length crossing the Mississippi.

The lines in Pennsylvania and New York are 4 inches, 5 inches and 6 inches in diameter, the pressure sometimes 1,500 lbs. per square inch, and the service continuous night and day. Some of the pumping stations cost as much as $75,000, and the pumps are of the compound condensing

type. Thus, this novel war measure, which seems to be a true solution of operations in the Soudan, presents no insurmountable difficulties to the hydraulic engineer.



[NOTE.—The map, photographs and lithograph referred to in Mr. Constable's paper are not reproduced. The plan and profile shown appeared on a larger scale in *Engineering News* March 7th, 1885, and were reduced, as here given, for *Science*. They are from a reconnoissance made in 1875 by H. G. Prout, then an officer on the staff of the army of Egypt.]

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

FEBRUARY 18, 1885 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P. M.; President G. L. Vose in the chair; twenty-three members present.

The record of the last meeting was read and approved.

The President called the attention of the Society to the death of Mr. Theophilus E. Sickles, an honorary member. On motion, it was voted: That the President and Mr. Thomas Doane be appointed a committee to prepare resolutions and such obituary notice as may be deemed proper.

The committee appointed at the last meeting to recommend an investment of the funds of the Society, presented a report and recommended the purchase of a plain five per cent. bond of the A., T. & S. F. R. R. The Treasurer reported that the funds had been invested as recommended by the committee.

On motion, it was voted: That the annual meeting be called at four o'clock P. M., and that the sum of fifty dollars be appropriated for the general expenses of the Annual Dinner, and placed at the disposal of the Committee.

On motion of Mr. C. W. Kettell, it was voted : That the sum of twenty-five dollars, or so much thereof as is necessary, be appropriated for binding the periodicals of the Society for the year 1885, and for other purposes in the Library.

On motion, it was voted: That a committee be appointed by the Chair, to prepare a list of candidates for the officers of the Society for the year 1885–6, and that the Committee be instructed to present three names for each office. The Committee appointed was Messrs. Brooks, French, Albert H. Howland, McClintock.

President Vose presented a communication from Mr. E. L. Corthell, inclosing a memorial to the President of the United States, praying such legislation may be had as shall admit of direct employment of civil engineers on government works, in such positions as they may be deemed competent to occupy. Also a communication from Mr. J. C. Prindle, Civil Engineer, U. S. N., recommending and advocating the selection of an experienced civil engineer as Chief of the Bureau of Yards and Docks. It was the opinion of the members present that the Society should take no action on these petitions.

Messrs. Ralph A. Quimby and Edward A. W. Hammatt were elected members of the Society.

Mr. Charles E. Putnam was proposed for membership, recommended by Messrs. F. P. Stearns and Seth Perkins.

Professor Gaetano Lanza addressed the Society on "Some Experiments on Belting Made at the Massachusetts Institute of Technology."

Mr. Albert F. Noyes read "A Description of the Foundations Placed Beneath the Pumps and Engines at the Newton Pumping Station."

[*Adjourned.*] H. L. EATON, Secretary.

MARCH 18, 1885 :—The annual meeting of the Boston Society of Civil Engineers was held and called to order at 4:40 P. M.; Vice-President L. Frederick Rice in the chair; forty-seven members present.

The record of the last meeting was read and approved.

The Annual Report of the Government was read and accepted, and on motion, it was ordered to be printed with the proceedings.

The Committee appointed to prepare a memorial on the death of Samuel F. Johnson, reported as follows :

CHARLESTOWN, Mass., March 7, 1885.

To the Boston Society of Civil Engineers:

I am now very glad to perform the duty assigned me February 21, 1883, of presenting a memorial of the late Samuel F. Johnson, who was one of the honorary members of the society, and who died at his home in Charlestown, Mass., early on the morning of January 15, 1883.

Mr. Samuel M. Felton writes me as follows concerning him :

"In the year 1834–5, after leaving Cambridge, I was at Charlestown, keeping a private school for boys. Among them were two brothers, one by the name of Samuel F. Johnson, the other William. Samuel was the elder, and a remarkably bright boy, I should say about fifteen years old. He was a good specimen also physically, fond of play and athletic sports, and equally fond of study when engaged in that.

"In 1836 I gave up this school, and at the invitation of Colonel Loammi Baldwin took charge of his office as an instructor of the young men then there as students in civil engineering. Johnson, George A. Parker, John Harris, Eben Baker, and several others of my pupils followed me into the office of Colonel Baldwin, and became students there. At the death of Colonel Baldwin, which occurred in June, 1838, I took the office and most of the business, and quite a number of the students remained with me.

"Johnson was employed in various ways in engineering, including the surveys of several railroads, and finally I appointed him as a Division Engineer on the location and construction of that part of the Fitchburg Railroad from Concord to Littleton. He was very attentive to his duties and particular in the character of all his work. If there was anything in which he particularly excelled, it was in masonry. On the completion of his work on the Fitchburg road, he was appointed one of the engineers on the Vermont & Massachusetts Railroad. He had charge of the western part of that road and Mr. Edwards of the eastern part. His work here was thoroughly and faithfully executed, and when that was done he was appointed Engineer and Superintendent of the whole road, and was a member of the New England Society of Railroad Superintendents.

"He subsequently was Engineer of the Troy and Boston Railroad, and completed that road and the depot in the city of Troy. The depot, greatly through his influence and exertions, was made accessible into and out of the city.

"From Troy he went to Chicago and became Engineer of the Chicago, St. Paul and Fond du Lac Railroad (now the Chicago and Northwestern road). It was then a struggling road, having a land grant to keep it along. When funds were wanting to pay the men, Johnson took a wood train and as many men as he could work, and went out on the track into the dense forests on this land grant, cut down the wood and timber, loaded the same on the cars, and hauled to Chicago and sold their contents there, paid the men, and thus for a time kept the work going.

"From this road he went to a road in Texas, under the temptation of a promised high salary. When the civil war broke out, Johnson, being a man of Northern birth and education, and with positive ideas of his own. did not fall in with the Texas notion of secession, and, as soon as he could get away, left the South and returned to Massachusetts, probably sacrificing a considerable portion of his accumulations for several years, as I understand he invested quite an amount in the Texas enterprise when he went there. Some time after his return to Massachusetts, he was appointed Engineer of Construction of the Old Colony Railroad, and

built the extension from Fall River to Newport. So far as I know, this was the last important work he did in engineering."

From other sources I have gathered the following: Mr. Johnson's father was Samuel R. Johnson, and his mother was by name Mary Bemis, and both of Charlestown. Mr. Samuel R. Johnson was a practical mason, working both in rough and cut stone. He died in middle life, from exposure in riding between the Quincy granite quarries and Charlestown. His son, Samuel Francis, was born December 16, 1821.

My own knowledge of Mr. Johnson began in 1842, when I entered Mr. Felton's office as a fellow-student with him. He was a large and powerful man physically, as Mr. Felton has said. He was about six feet tall, and weighed about two hundred and forty pounds. His deep voice was in consonance with his other powers. His tailor said that at nineteen years of age his chest measure was greater than that of any man of his age that he knew. During his boyhood he was the leading spirit as well as bodily presence among the Charlestown Pigs in their tests of courage and strength on the ice of Charles River, with the Chugs of the north end of Boston. He was always near-sighted. He was a great smoker.

His desire for and appreciation of good masonry for public works, he, no doubt, derived from his father and from acquaintance with works which his father was carrying on. His physical powers, with his determined will, gave him great influence among men with whom he had to do.

Since Mr. Felton's especial acquaintance with him ceased, I think Mr. Johnson built the Portsmouth and Dover Railroad. He leaves a widow, who was his second wife, and a son about eighteen years of age, Sidney Reginald Johnson, and a step-daughter. The disease of which he died resulted from his Texas experience. His grave may be found at Mount Auburn. THOMAS DOANE, Committee.

The Committee appointed at the last meeting to prepare a list of candidates for the officers of the Society for the year 1885-6 presented the following report:

President.	*Vice-President.*	*Secretary.*	*Treasurer.*	*Librarian.*
H. H. Bradley,	E. C. Clarke,	H. L. Eaton,	H. A. Carson,	A. E. Burton.
E. S. Philbrick,	C. W. Folsom,	F. P. Stearns,	T. W. Davis,	C. W. Kettell,
G. L. Vose.	L. F. Rice.	S. E. Tinkham.	H. Manley.	A. F. Noyes.

On motion it was voted: That a Committee be appointed by the Chair to receive, sort and count ballots. The Chair appointed as that Committee Messrs. A. W. Forbes, Hardy and McClintock.

On motion it was voted: That the officers be balloted for on one ballot.

The Society then proceeded to ballot, with the following result:

President, George L. Vose; *Vice-President*, L. Frederick Rice; *Secretary*, Horace L. Eaton; *Treasurer*, Henry Manley; *Librarian*, Albert F. Noyes.

Edward W. Howe was appointed Auditor by vote.

On motion it was voted: That the Committee on the Preservation of Timber be continued as at present constituted, with the name of Henry Manley added.

On motion it was voted: That the Committee on Excursions be continued, and that it consist of five, to be appointed by the Government.

On motion it was voted: That the name of the Committee on the Introduction of the Metric System be changed to the Committee on Weights and Measures, that its duties be so enlarged that it may include all the subject-matter as indicated by its name, and that the Goverment be requested to appoint this Committee.

On motion it was voted: That an assessment of six dollars be levied on resident members of the Society.

The Secretary announced that Mr. Charles H. Haswell had presented the Society a collection of minerals. On motion it was voted: That the Government be requested to extend to Mr. Haswell a proper acknowledgement.

Mr. Charles E. Putnam was elected a member of the Society.

The following names were proposed for membership: W. W. Wright, by G. W. Blodgett and W. Shepard; H. D. Woods, by A. F. Noyes and F. Brooks; W. A. Allen, by E. W. Howe and H. Bissell.

[*Adjourned.*] H. L. EATON, Secretary.

ANNUAL REPORT OF THE GOVERNMENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, FOR THE YEAR ENDING MARCH 18, 1885.

During the past year of the Society, there has been one death, that of Theophilus E. Sickles, an honorary member, who was first elected a member in 1848. A Committee has been appointed to prepare a suitable notice of the life and work of Mr. Sickles. Two resignations have been received during the year, and sixteen new members have been added. The net gain during the year has been thirteen. The total membership at the present time is one hundred and twenty-six, of which number six are honorary and two are corresponding members. Regular meetings have been held on the third Wednesday of each month, excepting July and August, and one special meeting was held January 14, 1885. The number of formal papers read during the year has been eighteen, and in addition there have been verbal communications and discussions upon various matters. The average attendance has been twenty-four, and a very decided interest has been shown in the work of the Society. Excursions have been made during the summer to the Improved Sewerage Works at Moon Island; to the Sudbury River Conduit, from Echo Bridge to Chestnut Hill Reservoir; to the Signal Towers at Boston and Riverside, upon the Boston & Albany Railroad, and to the Institute of Technology. These excursions have been exceedingly instructive and agreeable, furnishing not only an opportunity for a careful inspection of important works, but bringing the members together in a very pleasant manner, and promoting the free interchange of opinion upon various matters of engineering. It is hoped that such excursions will become a permanent feature in the proceedings of the Society.

At the meetings of September 17 and October 15, action was taken amending the Constitution in regard to the matter of dues.

The revised Constitution, the By-Laws, and a corrected List of Members has been printed and distributed.

From the report of the Treasurer we have the following in regard to the financial condition of the Society:

ABSTRACT OF THE TREASURER'S REPORT FOR THE YEAR ENDING MARCH 18, 1885.

Receipts.

Balance on hand, March 19, 1884		$298.79
Assessment for current year, 93 members at $6	$558.00	
Non-resident dues, " " 7 " " 3	21.00	
" " " coming " 16 " " 3	48 00	
		627.00
Interest on current balance		17.66
		$943 45

Permanent Fund Receipts.

Cash on hand, as per last report	$297.00
Entrance fees	162.00
Interest on bonds	97.00
Proceeds of called bonds	600.00
	$1,156.00

Permanent Fund Expenditures.

A., T. & S. F. Railroad 5 per cent. bond	$875.00	
Accrued interest and commission	23.47	
		$898.47
Cash on deposit		257.53
		$1.156.00

Disbursements.

Association of Engineering Societies	$408.00
Rent	45.00
Salary of Secretary	50.00
Binding	14.50
Printing Constitution	23.00
Printing notices, postage and stationery	78.21
Periodicals	29 55
Annual Dinner, 1884	19.50
Cash on deposit	263.69
Cash in hands of Treasurer	12.00
	$943.45

Funds of ths Society in the hands of the Treasurer:

A., T. &. S. F. Railroad 5 per cent bonds		$875.00
Republican Valley Railroad Co.'s 6 per cent. bonds		600.00
Permanent fund, cash	$257.53	
Current fund, cash	275.69	
		533.22
		$2,008.22

The Government recommends an assessment for the ensuing year of $6.

The Government is glad to announce that two societies have joined the Association of Engineering Societies during the year; those of Minneapolis and St. Paul. A meeting of the Board of Managers of the Association was held in New York, September 4, 1884, the proceedings of which will be found in the JOURNAL. In conclusion, we would call attention to the Index of Engineering Papers which is now published in the JOURNAL. It is proposed to make this as complete as possible, by reference to the engineering literature of all countries, so that members of the Society who may be engaged in any special lines of research may be able to see what other investigators are doing in the same direction.

(Signed) GEO. L. VOSE, President.
L. FREDERICK RICE, Vice-President.
HORACE L. EATON, Secretary.
HENRY MANLEY, Treasurer.
CHARLES W. KETTELL, Librarian.

MARCH 18, 1885:—The Annual Dinner of the Boston Society of Civil Engineers was held at Young's Hotel, Boston, at six o'clock P. M.; President Vose presiding and forty-eight members present. There were present, as guests of the Society, S. H. Scudder, H. L. Whiting, J. H. Shedd, A. S. Glover, C. T. Main, G. P. Lowe, F. D. Freeman, H. A. Allen, H. D. Woods, G. J. Fisher, Z. B. Adams.

After sufficient time had been given to the dinner, letters were read by President Vose from Samuel Nott, Charles S. Storrow, George A. Ellis, and E. S. Chesbrough, and introduced Mr. Henry L. Whiting, who defined what was expected to be obtained by the new topographical and geological survey of Massachusetts, and stated that the actual cost per square mile to date, for the topographical work, was about fourteen dollars. A map of the Connecticut River Valley within the State on a scale of $\frac{1}{30000}$ was exhibited.

Mr. Henry Mitchell, of the Mississippi River Commission, reviewed the work of that board.

Mr. Samuel H. Scudder, editor of *Science*, alluded to a project recently advanced in that journal, favoring the erection of a fire-proof building in the city proper, designed to furnish suitable accommodations, for society purposes, to the various societies interested in pure and applied science.

Major Charles W. Raymond responded to West Point and its influence in the education of civil engineers in the United States.

Mr. Thomas Doane referred to the railroad systems of the Middle and Western

States, their construction, equipment, and the impropriety of building competitive railroads not demanded by public necessity.

Mr. J. Herbert Shedd referred to the position occupied by the profession and the opportunities open before the younger members.

Mr. Alphonse Fteley alluded to the New York aqueduct in its general features, its capacity, location and profile, and the proposed form of cross-section of the Quaker Bridge Dam.

Mr. Eliot C. Clarke alluded to sanitary engineering and drainage, and the necessity of educating the public to the need of employing a sanitary engineer in the preliminary consideration of sanitary problems.

Professor Gaetano Lanza referred to the results of experiments on the transverse strength of wooden beams, made at the Massachussetts Institute of Technology.

Mr. George R. Hardy explained the economy of the original location of the Boston & Albany Railroad.

Mr. Charles W. Folsom referred to the earlier members of the profession, their practice and principles, as an example to modern engineers.

Mr. Desmond Fitz Gerald read an original poem on the Boston water supply.

H. L. Eaton, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

March 18, 1885 :—The Club was called to order at 8 p. m. by President Moore, twenty-five members and three visitors being present. Minutes of the last meeting were read and approved.

On motion of Mr. J. B. Johnson, the Club unanimously adopted the following :

"*Resolved*, That a committee be appointed to consider and report upon the best means of improving the status of civil engineers in the service of the general government."

Mr. McMath proposed an amendment to Sec. 7 of the By-Laws. As amended the section would be as follows, the second sentence being the amendment :

Sec. 7. Election of Members.

Candidates for admission to the Club as members shall be proposed by not less than two members at any meeting of the Club. [The proposal shall contain a statement, signed by the candidate, of his age, residence, qualifications for membership in the Club, and that he will conform to the requirements of membership if elected.] The proposal must be referred to the Executive Committee, etc.

Mr. J. B. Johnson read a paper on "The Theory of Car-Starters," which was discussed by the Club.

The President read a paper by Mr. Howard Constable on "The Proposed Water-Pipe Line in the Soudan."

Col. S. H. Lockett, who was one of the American officers in the service of the Khédive in 1875–6–7 as Chief Topographical Engineer, being present, spoke at some length as to the proposed pipe line and railroad. He was familiar with the country through which the pipe line is projected. and did not doubt its successful construction was assured. He thought the railroad projected would be built. The pipe line would aid such construction and be absolutely necessary to its maintenance. The climate was no bar to its settlement, for not considering the lack of water, there were no features of the climate against which objection could be brought. To obviate the lack of water the expedition with which he was connected made drive wells, from which good, constant supplies of water were obtained.

Prof. Johnson exhibited a French calculating machine, which excited considerable discussion.

[*Adjourned.*] Thos. D. Miller, Secretary.

APRIL 1, 1885:—The Club was called to order at 8 P. M. by Vice-President McMath, thirty members and four visitors being present.

Minutes of last meeting were read and approved.

Executive Committee reported that the resignation of Mr. E. Harrison and Mr. Samuel Rockwell had been accepted; also, that C. D. Lamb and J. C. Meredith had forfeited their right to membership by non-payment of initiation fee.

The amendment of Sec. 7 of the By-Laws, proposed at the last meeting, was adopted by a unanimous vote.

The following gentlemen were proposed for membership: Mr. O. A. Orrman, St. Louis, Mo., by Messrs. J. A. Ockerson and C. W. Clark; Mr. Walter S. Russel, Detroit, Mich., by Messrs. W. B. Potter and J. A. Ockerson.

Prof. F. E. Nipher read a paper on "The Efficiency of a pair of Holtz Machines, one acting as generator and the other as motor," which was discussed.

Mr. K. Tully read a paper on "Construction in Wood and Iron."

A general discussion followed.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

MARCH 17, 1885:—The 205th meeting was held at 4 P. M., President B. Williams in the chair.

In the absence of the Secretary, Mr. Liljencrantz was appointed to act as Secretary pro tem.

The minutes of the preceding meeting were read and approved.

The amendment to Article V., Section 2 of the By-Laws, as offered by Mr. L. P. Morehouse at the 203d meeting, was adopted.

[*Adjourned.*] G. A. M. LILJENCRANTZ, Secretary pro tem.

APRIL 7, 1885:—The 206th meeting was held at 4 P. M.; President Williams in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Artingstall, for Committee on Topics, reported a list of subjects on which the Society should invite papers.

It was voted that the report be referred back to the Committee for revision of the preamble.

Mr. E. J. Ward, an Associate, made application to become a member, and was elected as such.

The President, Trustee Wright and the Secretary, were appointed a Committee to arrange for quarters for the year beginning with May 1, with power to act.

On motion of Mr. Bates it was voted that members be requested to come prepared at the next meeting to suggest a practicable plan for obtaining discussions of topics at meetings of the Society.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

JANUARY 13, 1885:—Regular meeting held, President Holloway in the chair.

Minutes of last meeting were read and approved.

Upon the recommendation of the Committee on Membership, Messrs. George Paul and A. E. Mitchell were elected active members, and Mr. James A. Smith associate member of the club.

On motion of Mr. Laman the chairman appointed the following persons as a committee on nomination of officers of the club for the ensuing year: N. P. Bowler, J. A. Bidwell, Hosea Paul, C. M. Barber, N. B. Wood.

On motion of Mr. Whitelaw, the committee was instructed to present the names of two persons for each office, and to report the same at the next meeting.

By resolution the club expressed its desire that the annual meeting to be held in March should be similar to the last annual meeting.

Mr. W. R. Warner then read the paper of the evening, entitled, "Progress in Astronomical Telescopes."

On motion, Mr. Rawson was instructed to procure and present to Mrs. Crehore extra copies of the biographical sketch of the late John D. Crehore—by J. N. Stockwell.

Upon the resolution of Mr. Richardson, adopted November 11, 1884, in reference to the publication in other technical journals of matter read before the club, before it has appeared in the JOURNAL of the Association of Engineering Societies. the Chair appointed the following committee : A. Swasey, J. N. Richardson and John Whitelaw.

On motion, the Chair appointed the following Committee on Annual Meeting : E. H. Jones, H. M. Claflin, S. T. Wellman, W. P. Rice and A. Swasey. On motion, the President was elected chairman of the committee.

On motion, the Treasurer was directed to pay to the janitor of the building five dollars. M. W. KINGSLEY, Recording Secretary.

[*Adjourned.*]

FEBRUARY 10, 1885 :—Regular meeting held, President Holloway in the chair.

Minutes of last meeting were read and approved.

On recommendation of the Committee on Membership, Mr. W. H. Searles and Mr. J. H. Greenwood were elected active members of the club.

Mr. John H. Sargent then read a paper entitled, "Our Lake Front and its Possibilities."

On motion, the Treasurer was requested to furnish to the Committee on Membership a list of all members of the club whose annual dues are more than one year in arrears.

The Secretary was requested to ascertain and report the cost of printing 500 copies of the Amended Constitution, bound in convenient form for the pocket.

The Nominating Committee, appointed at the last meeting, reported the following ticket for officers for the ensuing year, presenting the names of two persons for each office as requested : *President*, J. F. Holloway and John Whitelaw ; *Vice-President*, Charles Latimer, and W. R. Warner ; *Corresponding Secretary*, E. H. Jones and N. B. Wood ; *Recording Secretary*, M. W. Kingsley and J. S. Oviatt ; *Assistant Recording Secretary*, F. C. Bate ; *Member of the Board of Managers of the Association of Engineering Societies*, M. E. Rawson and John Eisenmann ; *Treasurer*, S. J. Baker and A. Swasey.

The Committee on Annual Meeting made its report, which was received, and Committee continued. M. W. KINGSLEY, Recording Secretary.

[*Adjourned.*]

MARCH 10, 1885 :—Annual and regular meeting held at the Stillman House, Euclid avenue. President Holloway in the chair.

Minutes of last meeting were read and approved.

The President appointed the following persons as tellers, to count the ballots received by the Secretary for officers for the ensuing year : H. M. Claflin, J. L. Sterling and W. R. Warner.

The annual reports of the Treasurer, Recording Secretary and Member of the Board of Managers were read and ordered placed on file.

On recommendation of the Committee on Membership, the following persons were elected members of the club : Associate Members, James J. Smith, Wilson M. Day and W. E. Donnelly. Active Member, Prof. E. W. Morley.

A communication was received from the Civil Engineer's office, Brooklyn Navy

Yard, inclosing a Petition to the President, asking the appointment of a Civil Engineer as Chief of the Bureau of Yards and Docks.

Letters were read from Honorary Members Col. Charles Whittlesey and Col. J. M. Wilson, and from a former member, Rev. J. W. Brown, expressing regrets at their inability to be present at the annual meeting and banquet.

The tellers appointed to count the ballots for officers reported that the following persons had been elected: *President*, J. F. Holloway; *Vice-President*, Chas. Latimer; *Corresponding Secretary*, E. H. Jones; *Recording Secretary*, M. W. Kingsley; *Assistant Recording Secretary*, F. C. Bate; *Member of the Board of Managers of the Association of Engineering Societies*, M. E. Rawson; *Treasurer*, S. J. Baker.

President Holloway then delivered his annual address. After which the members and invited guests adjourned to the dining-room to partake of the annual banquet, at which 123 persons were present.

[*Adjourned.*] M. W. KINGSLEY, Recording Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

STEAMBOAT SHAFTS.

BY H. W. BAKER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read April 15, 1885.]

The shafts discussed in this paper are those in use upon our Western river steamboats, and as the ones which are troublesome on account of breakages are almost entirely confined to those of stern-wheel boats, this will limit our discussion in the main to them.

So prevalent is this breakage, however, that it has become a settled conviction with many good boat and engine builders that it is inevitable, and is only a question of time with any of them when they will thus fail.

Before we accept so fatalistic a conclusion, however, let us examine the facts bearing upon the subject, and see if they do not demonstrate, or at least indicate, the causes of failure, and suggest a remedy.

Method of Supporting a Shaft and the Forces Acting Upon It.—Upon stern-wheel boats the shaft is supported near each end, projecting beyond the pillow-blocks an amount only sufficient to receive the cranks, which are overhung and are placed at right angles to each other, one at either end of the shaft. Heavy cast-iron flanges are secured to the shafts at equal intervals between the pillow-blocks, and connect the wheel structure to it.

The stresses imposed upon a shaft are as follows : On the portion outboard from the pillow-blocks a torsional moment and a bending moment due to the pressure upon the crank pin, and another bending moment due to the weight of the crank and after half of the pitman.

On the inboard portion a torsional moment as before, a bending moment due to the reaction of the paddles and of the pillow blocks, and a bending moment due to the weight of the wheel itself plus whatever load it may carry in the form of ice.

Variable shearing stresses are also distributed throughout the shaft.

Notation.—W = weight of wheel and shaft (cranks not included).

l = length of shaft in inches from centre to centre of journals.

P = pressure of steam in cylinder per square inch.

A = area of piston head in square inches.

L = length of stroke of engine in inches.

r = radius of outer portion of shaft under consideration, or of inscribed circle when of hexagonal section.

r' = inner radius of portion of shaft under consideration (when hollow).

h = perpendicular distance between the faces of a hexagon.

p = maximum stress from bending.

q = maximum stress from torsion.

p_1 = maximum combined stress.

I = movement of inertia of cross-section.

E = coefficient of elasticity.

$M_\circ$ = torsional moment at any section.

M = bending moment at any section.

Now the pressure upon the crank pin is in an approximately horizontal line, or at right angles to the direction of the force of gravity ; therefore, in a round shaft, the particle under the greatest stress from the bending action of either of the forces outboard from the journal is at the neutral axis of the section of stress from the other force. The case of maximum stress is here taken as solved with sufficient accuracy by combining with the greater of these two stresses the maximum stress from torsion, by means of the formula for the ellipse of stress which for this case assumes the form, $p_1 = \frac{p}{2} + \sqrt{\left(\frac{p}{2}\right)^2 + q^2}$, and the angle which the maximum stress makes with the axis of the shaft is the one given by the formula $\tan 2\theta = \frac{2q}{p}$, θ being the angle, the stress from torsion being at right angles to the stress from bending.

The lever arm for the bending action of the force upon the crank pin is taken as the horizontal distance from the line through the centre of cylinder, to the middle point of the journal.

The above stress will be a maximum at the middle of the journal.

Stresses in the Body of the Shaft.—The section of this may be either circular or hexagonal. In either case, the same formula is used in determining the torsional stress, viz.: $q = \frac{M_\circ r''}{I}$, r'' being the distance from the centre of the shaft to the outermost particle. This formula considers the stress upon any particle to vary directly as its distance from the centre, and is exact for the circular section and nearly so for the hexagonal section.

Torsion.—The force opposite to the effort upon the crank-pin, which with that forms the torsional couple, is the reaction of the paddles, and is distributed uniformly along their entire length. The torsional moment may be taken as varying uniformly from a maximum at one journal to zero at the other journal for any given effort upon either crank-pin. This will give at the middle of the shaft a maximum moment equal to one-half of the maximum moment at the journal.

Bending.—As on the outboard portion, so there will here be two distinct bending actions at right angles to each other. One, whose forces act in a horizontal plane, due to the reaction of the paddles and of the pillow blocks, and the other, whose forces act in a vertical plane, due to the weight of the wheel, shaft and ice, and the greater of these at any section is the one whose stress is taken to combine with the stress from torsion at that section, as before.

Stresses from the Reaction of the Paddles and of the Pillow Blocks.—The stresses from bending arising from these are by no means easy to trace, and could only be determined accurately in any given case by very careful inspection and analysis of that particular problem.

The reaction of the paddles *per se* would cause a bending moment similar to that upon a beam supported at the ends and loaded at different points, being a maximum at the middle of the shaft and vanishing at the points of support. But the action of the forces outboard from the pillow blocks complicates the problem.

For, on the forward stroke of the engine, its force, causing a bending action on the shaft, is in the same direction as that of the reaction of the paddles, and they tend to break the shaft over the intermediate support and the ratio between the length of stroke and the diameter of the wheel; the pressure upon the crank pin, and the distances from the line through the centre of engine to the middle of the adjacent journal, and from middle to middle of journals, determine the amount and direction of the reaction of the farther bearing, and with that the stresses in the shaft. When the engine is on the after-stroke, the direction of its force is opposite to that of the reaction of the paddles, and the stresses in the shaft very different from the former case: but the ratio, lengths and pressure before used become again the determining factors for the reactions of the supports, and with them determine the stresses in the shaft under these new conditions.

But the exact solution of this tedious problem, with its somewhat ambiguous results, is scarcely of great practical moment, for the stresses thus imposed can only become the prominent bending stresses at or near the points of support, where the bending moment from the weight of the wheel is greatly reduced. At the middle of the journal it must equal that imposed by the crank pin action, which is the proximate cause. For the purposes of practical investigation, a sufficiently accurate approximation will be given by taking the bending moment at the middle of the journal, as determined by the pressure upon the crank pin, and considering it as varying directly with the distance therefrom, and vanishing at the further support; as the stress from the weight of the wheel soon becomes largely the greater one, when advancing toward the middle of the shaft.

Right near the journal a shaft is very liable to fail.

Stresses from the Weight of the Wheel.—The weight of the wheel may be taken as uniformly distributed over the length between the middles of the journals, and the stress due to it a maximum at the middle of the shaft; and of the value $p = \frac{Mr}{I}$. With this combine the stress due to the torsional moment at this point, by the formula

previously given, and the result will closely approximate the maximum stress at the middle of the shaft.

Deflection of Shaft at the Middle.—At the middle of the shaft, when long and carrying a heavy wheel, the deflection of the same becomes a serious matter. For it is quite obvious that a shaft, subjected to heavy stresses, forced into a constrained position and then revolved, being held meanwhile in this constrained and deflected position, the stresses from bending moments, being, at each revolution, completely changed from tension to compression and back again to tension, or *vice versa*, must be the victim of severe racking strains which must inevitably hasten its disintegration when these are of any great extent.

In fact, these two causes, the changing of the sign of the stresses with each half revolution, and the peculiar racking strains induced by the deflected position of the shaft, seem to be mortal.

The formula from which the deflections were computed is from Rankine and is as follows, deflection in inches $= \frac{5\ W\ l^3}{384\ E\ I}$, and this is multiplied by the coefficient, $\frac{4}{7}$, to allow for the stiffening effect of the wheel structure.

In the table appended, the maximum stresses were computed by taking those due to bending as simply the maximum tension or compression at any moment, whereas Wöhler's experiments on the fatigue of metals show that the difference between the limits of stress to which the metal is worked is the measure of the effective stress, and that even an elevation of limits, as long as they do not exceed the limits of elasticity of the material, only reduces the range through which it can be safely worked. To double the stress from bending, and take 85 per cent. of the result, would not be an exaggerated case, as 90 per cent. of the sum is no more than Wöhler's tables call for, and with this combine the stress from torsion. Examples of this are given in the table.

It will be noticed that any of these resultant stresses are very much too high for satisfactory results, and in corroboration of this evidence is the unanimity of testimony in regard to the appearance of a shaft when fractured, viz., that it will show a crystalline fracture, a well-known result of excessive strains.

That the length of shaft with its attendant phenomena is a great source of weakness, is evidenced by the comparative freedom from breakage of the shafts of side-wheel boats, in some of which the wheels are quite heavy, though always comparatively short. Each one on the "Bayou Sara" will weigh 25 tons, and on the "Will S. Hays" 33 tons, while the cast-iron shafts upon the "Jno. A. Scudder" have been in use there for twelve years, having previously worn out the "Marble City."

To remedy this, the experiment was formerly tried of dividing the wheel structure into two, and of putting an additional support under the shaft at the middle, and even of making two distinct wheels, but it did not prove satisfactory and has been abandoned.

Another factor which, though not constantly present, is liable to give rise to abnormal strains when present, is ice. The entire area of wheel surface upon the "Port Eads" is 5,030 square feet; a covering of ice on an average one inch thick over this would weigh 24,000 pounds, or an increase in weight of wheel and cranks of 37 per cent.

Upon the "Future City" the area of wheel surface is 5,590 square feet, and a covering of ice over this one inch thick would weigh 27,000 pounds, an increase of 35 per cent. in weight of wheel and cranks.

As an example of the possible abnormal stresses that may be imposed upon a shaft, take the following : On the "Future City," weight of wheel, 72,000 pounds ; add for ice, 26,000 pounds ; bending stress at middle from these weights, 10,895 pounds per square inch ; 85 per cent. of the double of this = 18,522. Combine this with the maximum stress from torsion which might occur where the wheel struck some obstruction and would be the double of that given in the table, and the resulting stress at the middle of the shaft is 20,560 pounds per square inch.

Again, take in the same manner the "Port Eads," and you will obtain a stress at the middle of shaft of 13,700 lbs. per square inch. No account is taken in either of these cases of any stiffening effect the ice upon the shaft itself may have.

An obvious remedy for both the excessive stresses and the deflection in shafts, without an inordinate increase in weight, is to make the shaft hollow, and to lighten the wheel structure by making it of iron as far a practical. As an example, take the "Future City's" shaft, and compare it with a hollow shaft of the same weight, with a shell 2 inches thick. The outside diameter of this shaft would be 33¾″, and the combined stress at the middle would be only 2,955 lbs. per square inch in place of 9,128 lbs., as now found. This is an increase in strength to over 300 per cent. of that of the present shaft. The deflection at the middle would be only .0433″.

The new shaft upon the "W. W. O'Neil" taken in the same manner would give a shaft 31.22″ outside diameter, combined stress at the middle 2,622 lbs., strength increased to 313 per cent. of that of present shaft, and deflection at middle .071″.

Again, take two-thirds of the weight of the last shaft, and treat it as before. This gives an outside diameter of 21.48″, combined stress at the middle 7,838 lbs. per square inch, deflection at middle .22″, an increase in strength of 45 per cent., with a reduction in weight of 33⅓ per cent.

Experiments have been made upon hollow shafts with various degrees of success. Upon the "Jno. R. Meigs" and the "C. B. Reese," sister boats of iron, their shafts were made of plate-iron, were 15″ diameter, the end sections $\frac{5}{16}$″, and the middle sections ⅜ inch thick, with 7″ laps double riveted, while the wheel itself was, with the exception of the buckets, entirely built of iron, the total weight of wheel and shaft being only 10,500 lbs.

On the "C. W. Howell" a similar shaft was used, 18″ diam., built in sections 5 feet long, of $\frac{5}{16}$″ iron. The sections were connected by heavy, circular diaphragm plates ⅝″ thick, which passed completely through the shaft and formed the flanges for the wheel arms. The sections of the shaft were secured to this by flanged fastenings firmly riveted, and the entire weight of the wheel was only 12,500 lbs.

On the "Horatio G. Wright," a side-wheel boat, the shafts were very similar to those upon the "Reese" and "Meigs," being 24″ diam., of ⅜″, $\frac{7}{16}$″ and $\frac{5}{16}$″ plate, and the wheel weighing only 23,000 lbs. The laps between sections were 16″ and 17″, well riveted, and with a cast hub inside and heavy bands shrunk on outside.

The stresses upon these shafts, it will be observed, are among the lowest of those given in the table, nevertheless they were all of them short-lived ; the one on the "Wright" scarcely running three seasons, and the others shorter times.

Doubtless, imperfection of workmanship is one cause of failures, for it would take very careful construction to make a riveted structure for such a service that would have no bolts drifted, and no initial stresses imposed upon it, and at the same time show no signs of looseness anywhere. It was to imperfections of this kind that the failure of the "Wright's" shaft was due.

The advantages for this form are, that a good uniform grade of material can be secured, and lightness, good disposition of metal for strength, and cheapness. But further disadvantages are found in the discontinuity of the metal and the abrupt changes in mass at the overlaps, butts and flanges, which give rise to numerous nodal points for the heavy vibrations induced by the wheel action to concentrate upon, and the effect upon so thin a sheet of metal is very liable to prove disastrous.

Although these experiments have not met with the success that was hoped and anticipated for them, this field can scarcely be said to have been exhausted ; but with generous factors of safety and good, careful workmanship, might be made a success, possibly. However, any built or riveted work in service, subjected to severe racking strains, labors under manfest disadvantages, and is inherently weak and vulnerable.

Hollow steel shafts have been made by forging the shaft solid and then boring out a central core of the desired dimensions. The hollow Krupp shaft recently placed upon the "Harry Brown" was made in this manner. Although the size of this hollow shaft is not sufficient to make any very radical improvement in strength as compared with the solid Krupp steel shaft which it replaced, nevertheless the facility which this affords for the examination of the interior of the forging, thus insuring against internal flaws, is a decided advantage.

Materials of Construction.—The advantages of iron for shafts, as manufactured in this country, seem to be the ability to work it at a high heat, and the comparatively uniform working of the metal. Then, too, the greater or less tendency to lamination arising from the method of piling the shaft is not without its advantages, for a crack started by an abnormal strain will often terminate with the lamina in which it originates and the shaft prove still serviceable for years ; whereas, with a homogeneous metal like steel the flaw, once started, will continuously increase and ultimately ruin the shaft. Steel, of course, has the advantage of great strength, and when properly worked, can be made somewhat lighter than an iron shaft of the same strength. Its disadvantages are, that it cannot be worked at so great a heat as iron without danger of injury; and at the lower temperature necessary, when in large masses, it is very liable to be of quite variable quality throughout the mass, the central portions being little else than the metal as cast in the ingot, while the outer portion is of a highly-wrought nature. In fact, the inherent defect and failure of steel shafts as made in this country is largely traceable to this as a cause, as numerous tests and experiments demonstrate.

Take the tests of the steel anchor bolts of the Illinois and St. Louis Bridge. There are 59 of these 30 feet long by 5¾ in. diameter, with the ends 6½ in. diameter. They were all tested to a stress of 40,000 lbs. per square inch. Twenty-seven bolts broke, some of them at the larger diameter and some with a stress of only 26,000 lbs. per square inch. Though some of the broken bolts showed evidence of injury from heat. others appeared perfectly sound, and none of the test specimens cut from these broken bolts showed a breaking stress of less than 100,000 lbs. per square inch.

The cause then assigned is doubtless the true one, viz., the improper forging with light hammers, which by extending the outer skin of the piece sets up high initial stresses within it, the interior being under high tension and the exterior under high compression, so that a slight additional stress would rupture a piece, any specimen cut from which would show good results.

Again, take the case of the United States dispatch boat "Dolphin," which broke her shaft upon her trial trip. This boat had an American-made steel shaft, and specimens tested from it after its failure gave the following results :

	Breaking stress.	Elastic limit	Elongation.
Test piece, cut from the centre of the shaft.....	54,000 lbs.	34,000 lbs.	2 per cent.
" " from the periphery	80,000 lbs.	32,000 lbs.	18 per cent

Now, although there was a flaw in the broken section, the above test demonstrates the great liability of breakage at any time.

Again, take the case of the tow-boat "Henry Lourey," which has broken two steel shafts of the same manufacture as the one above. These were hexagonal in section, 14″ between the faces of the hexagon, and 29′ ½″ between the centres of bearings. Each broke with about one year's service, and gave way without any warning whatever, much as a piece of glass would break, though the appearance of the fracture was that of a good steel.

That the trouble is mainly in the manufacture is evidenced by comparison with other steel shafts, notably those of Krupp's manufacture, which have been used somewhat extensively here.

Tests from the shaft broken upon the "W. W. O'Neil" show as an average elastic limit 39,400 lbs. ; breaking stress, 84,500 lbs. ; elongation, 19.2 per cent.; reduction of area, 34.1 per cent. These results, it will be noticed, are not far different from those from the outside of the "Dolphin's" shaft.

But the evidence of the homogeneity of the metal and its freedom from initial stresses is the fact of its running for some time after the cracks had started without entirely breaking through. The same can be said of the Krupp shaft broken upon the "Harry Brown." When discovered, the break in this was 9 inches long, and after three months of hard usage had extended only 1½ inches in length, and examination then showed that the crack was nowhere more than two inches deep. In both of these cases the table shows clearly that the failure was due to overloading. and the method of failure shows conclusively the excellence of steel for this purpose when properly worked.

Another evidence of the same fact is the much lower percentage of

failure in small shafts than large, even when subjected to equally high stresses.

Evidently the comparatively light hammers used by American steel manufacturers are not sufficient to secure the best results.

But the manifest advantages of a hollow shaft have led to some investigation in regard to them with the following results :

A hollow shaft can be cast of steel, for a reasonable price, and with the present great improvements in casting steel with reasonable assurance of securing a sound, serviceable article.

Tests of Otis steel from a cast ingot, 24″ diameter and 60″ long, gave as an average :

	Tensile strength. Lbs.	Elastic limit. Lbs.	Elongation. Per cent.	Reduction of area. Per cent.
From outside of cylinder...............	77,000	38,000	7.38	11.5
From inside of cylinder...	87,080	41,370	10.04	19.6

This cylinder was annealed after casting.

English manufacturers report the use of steel castings in even more formidable service than this, and experience no insurmountable difficulty in turning them out perfectly sound and with an average breaking stress of 36 tons per square inch.

The casting of a hollow steel shaft is an entirely feasible undertaking, and as the limit of the diameter for a given length and weight is only fixed by the thickness of metal requisite to insure a sound casting, it is readily seen that the evil effects of deflection and high stresses which are so universal can be brought within perfectly safe limits, and as the cost of these would be considerably within that of a good forged shaft, they are certainly worthy of a thorough trial. The continued use of solid cast shafts of steel on other machine work, with satisfactory results, would lead to the expectation of good results from these.

But by far the most promising in the way of a hollow steel shaft, though largely more expensive than the above, is one made by the process of Sir Joseph Whitworth & Co. (Limited), Manchester, England. In this the steel is subjected to a heavy hydraulic pressure immediately after casting, thus securing a perfectly sound and compressed steel, at the same time enormously increasing its strength, the tensile breaking stress reaching as high as 196,000 pounds per square inch. The piece is then forged to any desired shape and size by means of hydraulic pressure in place of a hammer. A hollow shaft is there forged upon a mandrel, and thus worked equally well upon both inside and outside, and certainly much more thoroughly and uniformly than is possible by means of any hammers.

A hollow shaft can undoubtedly be made by this process (they are already largely in use upon ocean steamers) that will be thoroughly reliable, and much lighter than those now in use. Their high first cost is against them, but even this is by no means as great as the cost of replacing a broken shaft, when the work of replacing and the delay in service is taken into consideration.

Name of Boat.	Shaft. Lengths. Over all	Shaft. Lengths. Between centres of journals	Shaft. Diameter of circle or distance between faces of hexagon. At middle	Shaft. Diameter of circle or distance between faces of hexagon. At end of body	Shaft. Form of section.	Shaft. Material	Journals. Length	Journals. Diameter	Weight of wheel without cranks	Maximum stress in journal. Pounds per square inch	Factors of Safety in Journal. Based on elastic limit of material	Factors of Safety in Journal. Based on breaking stress of material	Stresses in Body of Shaft at Middle. Pounds per Square Inch. From torsion	Stresses in Body of Shaft at Middle. From bending moment	Stresses in Body of Shaft at Middle. Combined	Factors of Safety at Middle. Based on elastic limit of material	Factors of Safety at Middle. Based on breaking stress of material	Computed deflection at middle, in inches	Dimensions of Engines. Diameter in inches	Dimensions of Engines. Stroke in feet	Steam pressure, pounds	Combined stress at middle of shaft, taking 85 per cent of twice the bending stress to combine with the torsional stress. Pounds per square inch	Remarks.	Life in years
	Ft. in.	Ft. in.	Inches	Inches.			Inches.	Inches	Pounds															
Harry Brown (old shaft)	38 7¼	.....	14½	14	Round	Krupp steel	.....	13½	88000	16580	2.41	4.82	4500	14300	15600	2.56	5.12	.7833	26	10	170	25116	Broken.	5
Harry Brown (new shaft)	36 7¼	.....	3 and 15⅞	3 and 15	Round and hollow	Krupp steel	.....	3 and 14¼	90000	10200	3.92	7.84	3500	11200	12200	3.28	6.56	.5581	28	10	170	19663		
Chas. Jutte	19 0¾	.....	6¾	6 5-16	Round	Krupp steel	.....	6⅓	20000*	22152	1.81	3.62	6329	16891	18908	2.10	4.20	.5424	13	6	180	30063	Broken.	3
Future City	33 10	30 0	15	14⅛	Hexagon	Krupp steel	.....	14⅛	72000	12500	3.20	6.40	3237	7891	9128	4.38	8.76	.3592	28	8	154	19071		
W. W. O'Neil (old shaft)	33 4⅝	.....	14	13¼	Round	Krupp steel	.....	13½	80000*	16143	2.48	4.96	6197	14866	16503	3.05	6.10	.7168	24½	12	165	26299	Broken.	1
W. W. O'Neil (new shaft)	33 4½	.....	16	14 7-16	Round	Krupp steel	.....	14	92000*	14474	2.76	5.52	3481	10295	11360	3.52	7.04	.4343	24½	12	165	18168		
Wm. Stone	21 3¾	19 5⅝	8	7 9-16	Round	Krupp steel	.....	7½	23400	19470	2.05	4.10	5900	13600	15000	2.51	5.02	.4831	15	7	160	24538		
Boaz	32 7	.....	13⅝	13¼	Round	Krupp steel	.....	13⅞	82000*	15113	2.64	5.29	4105	14118	15223	3.63	6.26	.6312	26	8	160	24680		
Port Eads	30 0	27 1	16	14	Hexagon	Iron	13	14	60000	12871	2.32	3.88	2771	4048	6192	5.31	8.08	.1701	28	8	160	12283		
Sidney Dillon	30 4¾	27 8½	16	13½	Hexagon	Iron	11½	13	51000*	9954	3.01	6.02	1677	4302	4852	5.18	10.30	.1548	22½	8	150	7679		
John Gilmore	29 11½	27 1½	14¾	13⅜	Hexagon	Iron	12½	13 3-16	67300	12840	2.33	3.89	2819	6040	7151	4.19	8.99	.2200	25	6	160*	10991		
Henry Lourey	32 6	29 0½	16	14½	Hexagon	Steel	14	14¼	87000*	13440	2.97	5.94	2787	7683	8803	4.65	9.30	.3041	26	9	176	13651		
Henry Lourey	32 4	29 0½	14	13½	Hexagon	Steel	14	13⅜	84000*	16253	2.48	4.92	4175	11087	12484	3.20	6.41	.5010	26	9	170	19731	Two shafts like this were broken.	Each 1 year.
R. S. Hayes	30 6	27 4 3-16	16½	.....	Hexagon	Iron	14 3-16	13¾	80000*	13963	2.14	3.58	2448	4565	5622	5.33	8.89	.1549	28	8	155	8453		
C. W. Howell	.....	22 0	18	18	Round and hollow	5-16 and ⅝ in. plate iron	8	7¼	12400	.....	.....	.....	2528	5421	6416	4.64	7.79	.1093	15	4½	160*	9864		
C. W. Howell	23 6½	21 10½	8½	8½	Hexagon	Iron	8	7½	30000*	15159	1.98	3.30	2983	13326	13963	2.14	3.58	.5627	15	4½	160*	23040		
C. B. Reese	22 9¼	21 2 11-16	15¾	15	Round and hollow	5-16 and ⅝ in. plate iron	8	7⅝	10500	.....	.....	.....	2499	4911	5956	5.03	8.40	.1054	15	4	160*	9039		
Phil E. Chappell	23 2	21 8	8	6	Hexagon	Iron	6½	6	18800*	12287	2.44	4.07	3100	22604	23021	1.31	2.17	1.3387	12	3	137	38647	Assumed weight of wheel probably too great.	
Chas. P. Chouteau	.....	34 3	13¼	12	Hexagon	Iron	13	12	83000*	11686	2.57	4.29	2729	15240	15714	1.91	3.18	1.0129	22	8	145	26193		
Mississippi	28 2	24 0	10	10	Hexagon	Steel	11½	9½	43000	15127	2.64	5.28	4343	12870	14198	2.81	5.63	.5560	20	6	160	22709		
Minnetonka	25 10½	23 5⅛	13	12⅛	Hexagon	Iron	10 9-16	12⅛	44300	13917	2.15	3.59	3289	5000	7368	4.08	8.78	.1873	22	8	165	11012		
John Dippold	31 4	28 3¼	12½	12	Round	Iron	.....	13	55000*	10982	2.73	4.56	3963	12164	13341	2.25	3.76	.5853	24	8	140	21412	Broken.	3 to 4.
John Dippold	31 4½	28 5¼	13½	13 7-16	Round	Iron	13¼	15	57000*	8840	3.40	5.85	3146	10066	10968	2.73	4.56	.4522	24	8	140	17672		

Coefficient of elasticity for iron taken at 30,000,000. Breaking stress of iron taken at 50 000. Elastic limit of iron taken at 30,000. Coefficient of elasticity for steel taken at 30,000,000 Breaking stress of steel taken at 80,000. Elastic limit of steel taken at 40,000.

In this table the items marked * are those in which the exact amounts were not obtained, but were approximated from the best information obtainable.

STEAMBOAT SHAFTS, BY H. W. BAKER, ENGINEERS' CLUB OF ST. LOUIS.

MILL CREEK SEWER.

By William Wise, Member of the Engineers' Club of St. Louis.

[Read February 4, 1885.]

We are sometimes reminded by publications descriptive of large sewers, of claims to superiority in size, which remain undisputed until a larger is heard from. For instance, in describing the Deptford sewer in Loudon, *Engineering* of May 23, 1884, referred to in *Engineering News*,* has the following ;

"This piece of work has a special interest, in that it is the largest sewer in London, and probably in the world, being 11 feet in height and 13 feet and 6 inches wide, and hence its construction marks an advance in sanitary matters." The length is given as 3,030 feet. While duly appreciating the magnificence of this admirable work, we beg to present for comparison in size the Mill Creek sewer, of St. Louis.

According to tradition, the name of Mill Creek is derived from Chouteau's mill, which, in the early history of the city, was situated near Ninth and Poplar streets, with a dam across the valley, creating a pond called Chouteau's Pond, somewhat irregular in shape and width, extending westwardly to Twenty-second street, a distance of a little more than a mile. (See accompanying sketch). This pond was said to have been a beautiful little lake so long as it remained unpoluted by the contaminating influence resulting from encroaching city improvements. Suggestions were even made to preserve and perpetuate the pond by enclosing it in a park to be established for that purpose, and there still remain with us a few old citizens who can boast of the sport and pleasure it afforded them in those good old days. In due course of time, however, as a consequence of the extension of the built-up city, the pond became a receptacle of filth, and in 1853 it was drained and the creek restored to its original channel.

Poplar Street Sewer.—One of the first steps taken toward the sewerage of Mill Creek Valley, made necessary by the threatening condition of the Creek, we find recorded in an Ordinance approved July 27, 1850†, establishing a sewer on Poplar street, from the river to Ninth street, to be 20 feet wide and 10 feet high. In October, the same year, the City Engineer, Samuel R. Curtis, in his report, after refering to the progress of Biddle Street Sewer, then in course of construction, says :—‡

"Another large sewer should be constructed to drain the valley of Mill Creek, including the pool of the dam known as Chouteau's Pond." Then, after describing the filthy condition of the pond, and the sanitary reasons for draining the same, he further says :—"If it is thought necessary to retain the mill power for the benefit of the proprietors of the land, this can be effected also. A double sewer may be constructed above the mill, one receiving and carrying the subterraneous and surface water through and on to the machinery of the mill, the other a small one,

* *Engineering News*, June 21, 1884. † Ord. No. 2,485.
‡ City Eng. Report, October, 1850.

should be constructed below this, and deep enough to drain the adjacent ground and receive the offensive sewage of this portion of the city. * * * * * * * * * * * * But I do not hesitate to say, this will be the first application to mechanical purposes of the drainage of a city."

In 1851 the construction of Poplar street sewer was commenced, and a section from the river to Main street was completed the following year, after which the work was carried on simultaneously from Ninth street, eastwardly, and from Main street, westwardly. But judging from the reports of the City Engineer, the work was attended with difficulties not easily overcome. A troublesome stratum of quicksand was encountered near Second street, which the contractors were unable to successfully contend with, and it was found on examination by borings that near Third and Fourth streets it was still worse, and the excavation seemed so precarious that it was considered impracticable to construct the sewer without great risk and danger of undermining the buildings along the street. The character of this formation is described by the City Engineer, Col. J. B. Moulton,* as "30½ feet in depth of quicksand so volatile that when in boring the augur reached the stratum, it penetrated the mass eight feet by its own gravity." This is given as a reason for releasing the contractors, Messrs. Shanks & Fox, as provided by Ordinance No. 3,408, and a sewer in or near the Mill Creek Channel is suggested, utilizing the old culverts at the street crossings, and their extension through portions of the blocks between Main and Third streets.

The following year (1856) the City Engineer, Henry Kayser, proposed to overcome the difficulties on Poplar street by first constructing a small sewer 3½×5 feet, with open cross-joints, with a view of draining the water from the sand, after which it would be practicable to construct the sewer full size.† Proposals were invited and bids received for this sewer of reduced size, ranging from $14 to $83 per linear foot, but nothing seems to have been accomplished by this plan. Experiments were subsequently made by various parties at their own expense.

One of the methods tried is described by the City Engineer. Henry Kayser, as follows: "He (the contractor) has sunk by means of a shaft a strong boiler-iron tube, oval shape, about 6 feet long, which he expects to move forward by means of hydraulic pressure, or screws, and under the protection of and within which the tunnel excavation and building of sewer is to be carried on."‡ After experimenting in various ways unsuccessfully, and at an expenditure of about $60,000, the work was finally abandoned in 1857, leaving a gap between the two sections of about 1,165 feet.

In reference to the size and capacity of the Poplar street sewer, we find in the ordinance above cited that "it shall be 20 feet wide and 10 feet high." (Rather odd shape.) And the City Engineer, Col. Samuel R. Curtis, with a view to determine the requisite size, refers to the old culvert across Seventh street as having a sectional area of 200 square feet, and "receiving and discharging the water during the heaviest storms

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* Report of City Eng., Oct., 1855. † Report of City Eng., Oct., 1856.
‡ Report of City Engr., May, 1857.

with only a slight head ;" and suggests, "as this is no more than sufficient, it gives us a minimum size below which we cannot go."*

It would appear that this important feature was at this time duly considered, resulting, however, in the adoption of a size somewhat less than the above recommendations would warrant (see Fig 3). This size (15 feet diameter) was carried out in the construction of the section from Ninth street eastwardly, and from the river to near Main street, but for some unaccountable reason it was reduced to 11½ × 12½ from Main street to Second street.

The eastern section has since been utilized as an outlet for the sewerage of the district lying between Main and Fifth streets, from Plum to Walnut street, embracing an area of about 60 acres.

Granting the practicability with the aid of modern improved appliances, the Poplar street sewer might possibly, in the distant future, be made to serve as an auxiliary to Mill Creek sewer by completing and extending it westwardly to Twentieth street, so as to intercept the drainage of Campspring sewer, and the intermediates on Eighth, Ninth, and Twelfth streets, relieving Mill Creek sewer of a drainage area of about 1,000 acres. If this should ever become necessary, as it is deemed probable that the capacity of the sewer may be insufficient when the entire water-shed is built up.

If the sewer on the Poplar street route had been successfully carried through, and made the proper size, a distance of about 800 feet would have been gained, with a straighter sewer, but even if this had been accomplished, a comparison with the route adopted for Mill Creek sewer, considering all the difficulties to be encountered on the former, would result in favor of the circuitous route through the valley of the natural channel.

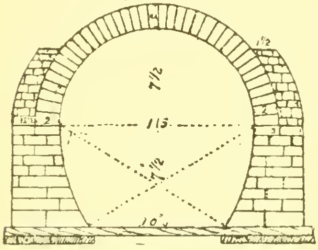
Establishing Mill Creek Sewer.—The abandonment of the Poplar street sewer project in 1857, left the question of the sewerage of Mill Creek Valley, to be started on a new base, and after a brief halt we find the first substantial move in an ordinance approved March 10, 1860,† "establishing and re-establishing all public sewers throughout the city, as far as streets are laid out." This ordinance located Mill Creek sewer on Chouteau avenue, from the river westwardly to its intersection with Mill Creek at Sixth street, thence westwardly as nearly as practicable along the creek; the first part on Chouteau avenue being subsequently changed to Sycamore street (now Lasalle street) one block south of Chouteau avenue, and the sewer as finally constructed follows this route, meeting Cerre street between Sixth and Seventh streets, thence westwardly on Cerre street to Tenth street, and diagonally across the blocks to Gratiot near Twelfth street, on Gratiot to Fourteenth street, and along the south side of the Missouri Pacific Railroad to the creek west of Eighteenth street, thence diagonally across the blocks to Lasalle street near Missouri avenue, on Lasalle, to Joab street, thence diagonally across to Compton avenue and Gratiot street, and along the south side of the Missouri Pacific Railroad, and on Atlantic street to Prospect avenue, thence crossing the Missouri Pacific Railroad and the St. Louis & San Francisco Railroad to

* Report of City Engr., May, 1851. † Ord. No. 4621.

Cabenne avenue, and along the south side of the Wabash, St. Louis & Pacific Railroad to Vandewater avenue. The extension will be in a northwesterly direction to Newhouse and Easton avenues.

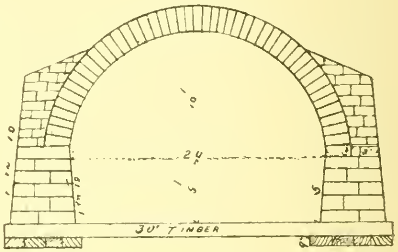
Drainage Area.—The sewer is designed to drain a portion of the city, embracing about 6,400 acres, or ten square miles, the watershed of which diverges from a comparatively narrow space near the river, to a width of about 4¼ miles in the western part, where it reaches beyond Easton Avenue on the north, to beyond Arsenal street on the south, bounded on the west by the ridge near Taylor Avenue and King's Highway (as shown on the accompanying sketch.* About one-third of this area is built up, and the improvement of the remaining portion may be considered as only a question of time. In addition to this territory, which is the natural watershed, and for which the sewer is intended to carry the combined storm water and sewage, it is contemplated to extend a branch westwardly across the dividing ridge, to intercept the house drainage of a large district otherwise tributary to the River Des Peres, threatening to endanger the sanitary condition of that stream—one of the embellishments of Forrest Park.

FIG 3



SECTION of a PORTION of POPLAR ST SEWER

FIG 4



SECTION of MILL CREEK SEWER ON TIMBER FOUNDATION

Length and Dimensions.—The finished portion of the sewer is about 3¼ miles long. The main stem to Vandeventer avenue will be nearly 3¾ miles, and the northwest extension will add about 2½ miles, making the total length when completed to Newhouse and Easton avenue, a little over 6 miles. Beyond this the still further extension will probably be made and classified as a district sewer.

The outlet at the river is divided into a double sewer, each 15 feet wide by 10 feet high, so as to keep the crown of the arch under the surface of the wharf, and shorten the open channel from the mouth of the sewer to the river (as shown by Fig. 1).

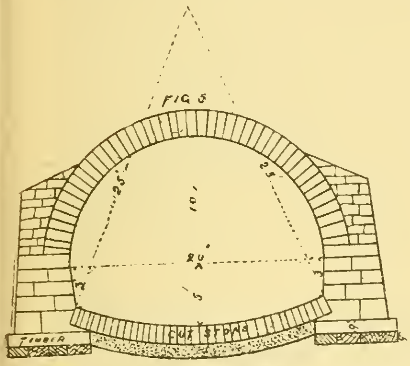
The length of this section is	70	feet
From this outlet section the sewer is 20 feet wide by 16 feet high, a distance of	575	"
Thence 20 feet wide by 15½ high	797	"
Thence 20 feet wide by 15 high	14,947	"
Making the total length of sewer 20 feet wide Or 3 1-10 miles.	16,389	feet

The section now under construction from Theresa avenue to Prospect

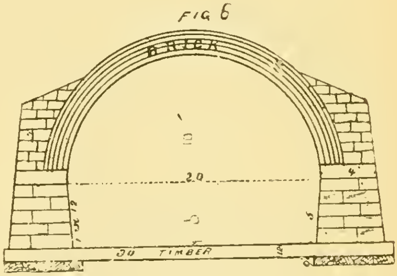
* The sketch is made on a section of a city map prepared by Robert Moore, C. E., accompanying his paper on Public Sewerage and House Drainage, read before the American Health Association, October, 1884.

avenue, 851 feet of which is completed, is 18 feet wide by 15 feet high (as shown by Fig. 8), and this size will be continued to Vandeventer avenue, a further distance of about 2,460 feet, making the main stem 19,700 feet, or nearly 3¾ miles, as above stated. From this point, where a large branch sewer from the south, will connect, nearly equal to the continuation of the main sewer, the size will be diminished to about 12 by 14 feet, with further proportional decrease, as the limit of drainage is approached.

Grade.—The bottom of the sewer at the outlet is 5½ feet above low-water mark, and the inclination, or grade, is 1½ feet per 100 in the first 300 feet, 1¼ per 100 for the next 370 feet, thence it varies from 1 per 100 to a minimum of 1 per 1,000, falling in the first three miles just 50 feet, of which the first mile falls 28 feet, the second 13 feet, and the third 9 feet. The grade on the section now under construction is 1¼ per 1,000, which will be continued to Vandeventer avenue: and the fall in the



SECTION OF MILL CREEK SEWER
WHERE INVERTED ARCH IS SUBSTITUTED FOR TIMBER BOTTOM



SECTION OF MILL CREEK SEWER
WITH BRICK ARCH AND TIMBER BOTTOM

fourth mile will be about the same as that of the third (9 feet.) The fifth mile will fall about 16 feet, and the sixth about 31 feet, making the entire fall in six miles 106 feet.

Construction Commenced.—The first contract for construction was let July 24, 1860, and the work was commenced the following month on the section from the south side of Chouteau avenue and Sixth street to a point west of Seventh on Cerre street. The location of this section was nearly all the way in or near the old Creek Channel, and crossed the streets at the old culverts under Chouteau avenue, Papin street and Gratiot street, at depths respectively of 29½, 34, and 26¼ feet below the street surface, this being one of the two places where a defective foundation, under a too heavy weight, subsequently caused the work to settle and break, necessitating reconstruction. The old culverts having served many years, and still apparently in good condition, may have had some influence in determining the sectional plan of the sewer. They were made of stone masonry on timber foundation, and when taken

up, the timber was found in a perfect state of preservation, and was again used in the bottom for the sewer. Fig. 4 shows the section for this portion of the sewer, the form of the interior being the same for the first three miles up to Ranken avenue, but the thickness of the walls and bottom timber varies with the different sections, the timber being 9 inches thick in the sections first made between Sixth and Twelfth streets, and 12 inches thick in all the other portion where timber was used. The arch is uniformly two feet thick, where it is made of stone, which is from the river to Compton avenue. From this point westwardly the sewer has a brick arch 22 inches thick. The side walls at the spring-line of the arch are 3½ feet thick from Sixth to Twelfth street, and 3¾ to 4 feet on all the other part of the sewer up to Theresa avenue.

Excavation.—The character of the excavation is mostly through alluvial formation, the sewer resting on a foundation of stiff blue clay, except where the location is a considerable distance from the creek, when rock was encountered, with overlaying red clay. From the river across the wharf the excavation was through filled ground, with soft mud foundation. The sewer through this, as also a short portion between Main and Second streets, was set on piles. The rock excavation is from Second street to a point near Third street, a distance of about 300 feet, from a point between Seventh and Eighth streets, to Tenth street, 750 feet, and from Sixteenth street to the creek west of Eighteenth street, 1150 feet, aggregating a distance of 2200 feet. The depth of excavation was from two feet to 36 feet, and averaged about 17½ feet, but, since filling up to grade, the depth of the sewer is from 19 to 36 feet, averaging about 25½ feet. The least depth of filling on top of the arch is two feet, and the greatest is 19 feet.*

Stone.—The stone, when the work was first commenced, was taken from the limestone quarries in and near the city, but about this time the Grafton quarries, near the mouth of the Illinois River, were opened, and the superiority of this stone† on account of its uniform straight and smooth beds, and ledges of any desirable thickness, and easily cut, soon gained for it such a reputation that it was generally selected for most of the heavy masonry in and about the city, and very little other stone has since been used for the sewer, except the portion from Jefferson avenue to Joab street, about 1,954 feet in length, for which the stone was brought from the Eureka quarrries on the Missouri Pacific Railroad, about 30 miles from the city. In a few sections, however, the haunching of the arch is of stone from the city quarries.

Cement.—The cement for the entire work is of the Louisville brands, excepting the section under the first and part of the second contracts, where the Utica cement was used. Since 1876 all the cement used has been tested with a Fairbanks machine. The tensile strength required is 40 pounds per square inch, neat cement, when 30 minutes in air, and 24 hours in water, but the actual breaking strain of all used has averaged about 70 pounds. The mortar is composed of one part cement to two parts sand; the sand was procured by dredging and from the bars in the Mississippi River.

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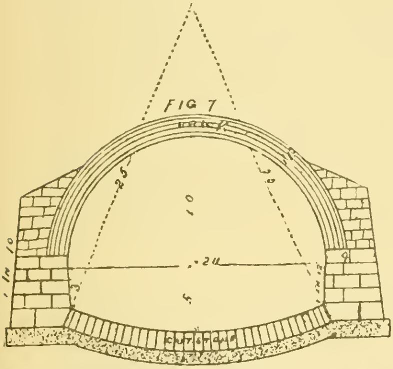
* See accompanying profile. † Magnesian limestone.

Timber.—The foundation, or bottom timber, is mostly cottonwood up to Compton avenue, and yellow pine from Compton to Ranken avenue, the end of the timber bottom. The experience with timber bottom (although no defects are found in any portion of the sewer where the timber is 12 inches thick), has resulted in a change of sectional form, for the extension of the sewer west of Ranken avenue similar to that reconstructed with inverted cut stone arch on concrete foundation, as represented by Fig. 7.

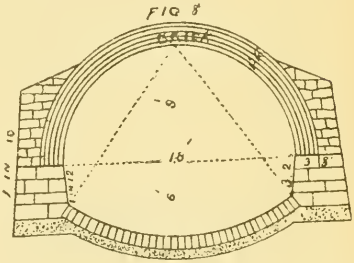
In July, 1880, a portion of the sewer about 263 feet long from Twelfth street eastwardly, and 222 feet long from Papin street northwardly, settled, breaking the timber bottom and masonry to such an extent that it had to be taken up and rebuilt. The cause of this failure is very elaborately described by the Sewer Commissioner, Mr. Robert Moore, in his Annual Report of April, 1881, and is attributed to a defective foundation, insufficient to sustain the weight of the heavy embankment, which at these points is about 36 feet, measuring from

FIG 7



SECTION OF MILL CREEK SEWER with CUT STONE AND CONCRETE FOUNDATION

FIG 8



SECTION OF MILL CREEK SEWER WEST OF THERESA AVE.

the sewer grade, or 19 feet on top of the arch. The bottom of the sewer at both places was made of 9 inch timber, reaching across the sewer and under the sidewalks, resting on a longitudinal base course of the same thickness, under the walls. The location here is in and along the creek-bed, and the timber was laid on the alluvial formation, which is a stiff blue clay, and might have answered the purpose if the timber had been of sufficient thickness, as it has proved so elsewhere under similar conditions with this exception. It may also be said that where the embankment is comparatively light, as on Cerre street, at and near Seventh street, the sewer on 9 inch timber is in perfectly good condition. Fortunately but little remains from which any trouble may be apprehended.

The reconstructed sewer is set on piles with 12 inch timber bottom, the sectional form being the same as originally. At each end of both sections, as far as any disturbance of the walls or foundation could be observed, the timber bottom was cut out, and an inverted arch of cut stone 18 inches deep, on a bed of concrete 12 inches thick, was inserted,

(as shown by Fig. 5). Five hundred and eight linear feet was treated in this way, and it was at one time considered advisable to continue the same until all the 9 inch timber bottom was thus substituted. Accordingly a section from the rock bottom at Tenth street, westwardly to that already done near Twelfth street, a distance of 617 feet, was put under contract and is now nearly completed. This will leave about 1000 feet of 9 inch timber bottom, but most of it (as above stated), is under a comparatively light weight, and will probably need no further attention.

The cost of this work for the section now being done is $25.95 per linear foot, and the average cost of that previously done is about $32.40 per linear foot.

An accident, resulting from the repairs mentioned, was caused by large timbers, used for props and shoring, together with fragments of the old bottom timber cut out, and being exposed to sudden showers, was washed down the sewer and lodged against the dividing pier at the outlet, creating a dam and choking the sewer, so that a heavy rain-storm lifted a portion of the arch where it had but very little covering * and overflowed the low ground in the vicinity of Second street on Convent, and Rutgers streets, where the street surface is from three to five feet lower than the surrounding grades, forming a basin, the drainage of which is entirely dependent on the sewers.

This unfortunate occurrence could happen only from a chain of circumstances not likely to be repeated. While the work of repairing, furnished the materials grasped by the storms, the unusual long-continued stage of high water in the Mississippi River completely submerged the mouth of the sewer so as to be inaccessible for inspection, and the hidden danger remained undiscovered until too late.

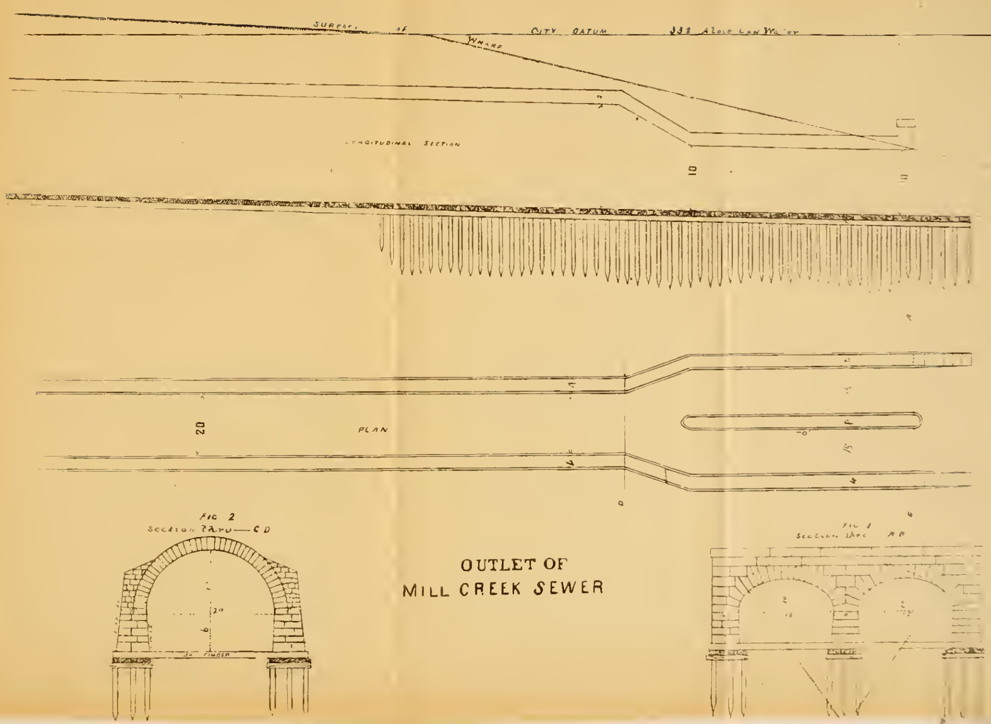
No engineering difficulties worthy of note were encountered in any part of the work, and nothing occurred in its progress, requiring any but the ordinary methods. No attempt has been made by any of the contractors, to use modern improved excavating machinery, such as has been successfully applied elsewhere, the steam derrick being the principal instrument for handling all materials in excavation and masonry.

The crossing of water pipes and gas pipes generally required careful propping. In some cases the pipes were taken out for the time being, but this could only be done where it did not interfere too much with the supply. One case may be given for example, although not applicable to some others much more difficult: On the section now under construction on Grand avenue a 30 inch main pipe through which the water is forced from the pumping works at Bissells Point, to Compton Hill Reservoir, is laid in an embankment about 8 feet below the surface and 3 feet above the top of the sewer. Before reaching the pipe with the work, a section of the sewer 15 feet long, was first constructed immediately under the pipe, which was supported by timbers resting on the banks at each end of the excavation. On this short section the pipe was permanently supported, and the work proceeded without further hindrance.

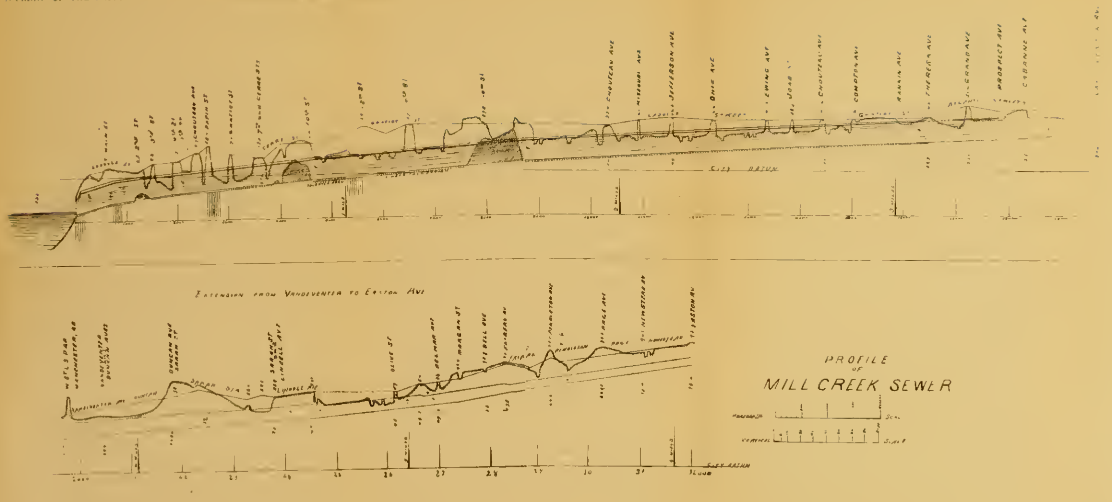
Constant vigilance was required by the contractors to guard against rain storms. The creek channel, in many places where it crossed the sewer route, could not be diverted, and conduits would answer only for

* The covering on the arch at this point, is the minimum of two feet.

DRAINAGE DISTRICT OF MILL CREEK SEWER



OUTLET OF MILL CREEK SEWER



PROFILE
OF
MILL CREEK SEWER

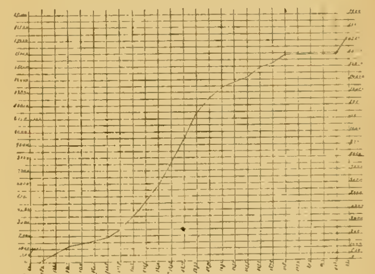


Diagram Showing Progress of Construction of
MILL CREEK SEWER

the dry weather flow, so that the storms would sometimes wash away portions of the work, leaving deposits of mud and filth, and causing considerable damage to the work. The latest accident of this kind happened on the 26th September last, on the section now in progress just east of Grand avenue; about 25 feet of the arch was washed away, and the sewer, which is not yet connected with the finished work, was filled with mud and water, causing some delay and unpleasantness.

The progress of construction, since the beginning in 1860, has been almost without interruption up to the present time, with the exception of about 4 years from October, 1879, to October, 1883.

Right of Way.—The cause of this delay was partly from the lack of funds, the proceeds of the bonds issued for this work having been exhausted, but the principal cause was on account of the delay in procuring the right of way through private ground. Up to this point the right of way was acquired with but little expense and without much trouble, the only spot that appeared somewhat costly was between Sixteenth street and Eighteenth street, where a clay-pipe factory was in the way, which cost the city $15,000.

From the wharf to Fourth street, a distance of 1,720 feet, the cost for right of way was	$3,934.70
From Fourteenth street to the railroad bridge west of Eighteenth street, including pipe factory, a distance of 1,430 feet	22,286.36
From railroad bridge aforesaid to Lasalle's, near Missouri avenue, a distance of 2,060 feet	1.00
From Joab street to Gratiot street west of Compton avenue, a distance of 1,340 feet	1.00
From Ranken avenue to Theresa avenue, a distance of 497 feet	750.00
Making the total cost for right of way up to Theresa avenue	$26,973.06

The greatest obstacles in procuring the right of way were mostly found where least anticipated, and where the value of the property is largely dependent on the construction of the sewer. For instance, on the section now in progress from Theresa avenue westerly a distance of about 410 feet, the sewer is located on Atlantic street, along the south side of the Missouri Pacific Railroad. The street not having been dedicated to public use (though used as such), the owners of the lots fronting on the south side obtained the sum of $4,500 and the guarantee of a substantial and unobstructed plank road along the sewer to a slaughter-house on one of the lots, the vast benefits to be derived on account of the construction of the sewer being entirely ignored. A section from the west end of the work under construction on Prospect avenue, a distance of about 1,080 feet, has been opened at a cost of $2,463, and the remainder of the route to Vandeventer avenue is in process of opening, so that no further delay in carrying the work to completion is apprehended on this account.

Cost.—The cost of the sewer may be estimated about as follows:

For the completed work up to the present time, including maintenance and repairs	$1,390,558.19
For cost of right of way procured	33,936.06
Estimated cost of right of way yet to be obtained	3,000.00
Estimated cost to complete the work under contract	31,000.00
Estimate for remainder of the main stem to Vandeventer avenue	100,000.00
Estimate for extension from Vandeventer to Newhouse and Easton avenues	230,000.00
Making the entire cost of the sewer when completed	$1,788,494.25

The principal items and time of construction of each section of the sewer are tabulated as follows :

Location.	Date of construction.	Size in feet	Length in feet.	Cost.	Cost per lineal foot	Materials.
From River to Main street	Sept., 1868, to April, 1871..	15×10 Double 20×16	70 575	$80,621.97	$125.00	Stone masonry on timber and piles.
From Main to Third street.	May, 1869, to May, 1871 ...	20×15½	797	77,956.79	97.81	Stone masonry on timber and on rock.
From Third to fourth street.......	June, 1868, to March, 1870..	20×15	520	45,355.22	87.22	Stone masonry on timber.
From Fourth to Sixth street	May, 1866, to May, 1867	20×15	272	32,232.53	118.50	Stone masonry on timber.
From Sixth to Seventh and Cerre st.	Aug., 1860, to May, 1864....	20×15	1,432	69,647.22	48.64	Stone masonry on timber.
From Seventh to Tenth street......	Oct., 1863, to July, 1867....	20×15	952	74,481.93	78.23	Stone masonry on rock and on timber.
From Tenth to Twelfth street.......	March, 1867, to Oct., 1868..	20×15	1,000	95,085.30	95.08	Stone masonry on timber.
From Twelfth to Fourteenth street.	Sept., 1868, to March, 1870.	20×15	754	71,735.19	95.14	Stone masonry on timber.
From Fourteenth to Sixteenth st...	Oct., 1869, to Aug., 1871 ..	20×15	800	72,552.59	90.69	Stone masonry on timber.
From Sixteenth to Eighteenth st. ..	April, 1881, to Nov., 1872. .	20×15	630	57,886.82	91.88	Stone masonry on rock
From Eighteenth st. to RR. Bridge.	March, 1870, to Nov., 1872..	20×15	970	57,340.25	59.12	Stone masonry on rock.
From RR. Bridge to Chouteau av...	June, 1870, to May, 1873....	20×15	1,332	101,075.25	75.88	Stone masonry on timber
From Chouteau av. to Missouri av..	April, 1872, to Oct., 1873. ..	20×15	795	62,522.95	78 64	Stone masonry on timber
From Missouri to Ohio av..........	May, 1872, to May, 1874....	20×15	1,113	77,021.56	69.20	Stone masonry on timber.
From Ohio to California av.........	June, 1873, to Sept , 1874...	20×15	841	60,522.54	71.96	Stone masonry on timber.
From California av. to Joab street..	Sept , 1874, to Aug., 1875..	20×15	770	55,684.77	72.32	Stone masonry on timber.
From across Joab street...........	Sept., 1873, to April, 1874 ..	20×15	150	10,417.90	69.46	Stone masonry on timber.
From Joab street to Compton av. ..	Oct., 1876, to March, 1878 ..	20×15	1,195	59,715.67	49.97	Stone masonry on timber
From Compton to Ranken av.......	June, 1878, to Oct., 1879....	20×15	924	37,110.13	40.16	Stone sidewalls, brick arch, and timber foundation.
From Ranken to Theresa av...	Oct., 1883, to Nov., 1884....	20×15	497	29,956.80	60.27	Stone sidewalls, brick arch and cut stone on concrete foundation.
From Theresa to Prospect av	April, 1884. In progress....	18×15	851	41,436.50	48.69	Stone sidewalls, brick arch and cut stone on concrete foundation.
					$73.68	=Average for construction.
Miscellaneous work and repairs ...	....	....	....	120,198.31		
Total..........	....	....	17,240	$1,390,558 19		

The quantities of the principal items of the work done up to the present time are about as follows :

	Quantities.	Prices	Average prices
Earth excavated.	450,000 cubic yds.	From 21.77c. to 94c. per cubic yd. Excepting 3,895 cubic yds., which cost at the rate of $1 99¼ per cubic yd.	53¼ cts.
Rock excavated.	26,000 " "	From 0 to $2.57½ per cubic yd.	60 cts.
Stone masonry..	92,360 " "	From $4.25 to $14.67 per cubic yd.	$9.09
Brick masonry..	5,550 " "	From $4.20 to $11.00 per cubic yd.	6.67⅓ cts.
Concrete.......	2,000 " "	....	5.00
Timber.........	6,222,000 feet B. M.	From $18.00 to $32.50 per M.	24.06
Piling.........	60,000 lineal feet.	From 52c. to 60c. per ft.	56 cts.

Funds.—The funds for construction were provided, first from the general revenue, until an act was passed by the General Assembly, approval Feb. 20th, 1868, authorizing the issue of bonds to the amount of one and a half million dollars to aid in the construction of public sewers, of which the proceeds of $900,000 was applied to Mill Creek Sewer, and the remainder to Rocky-Branch Sewer, Arsenal street sewer, Southern Sewer and branches. This carried the work up to Ranken avenue, since which the funds are again derived from the general revenue.*

The extension of the sewer will meet with no serious difficulties after the next section from Prospect avenue to Cabanne avenue is passed, but the construction of this section will be somewhat troublesome on account of the railroad tracks of the Missouri Pacific and the St. Louis & San Francisco railroads crossing at this point.

We may hope that the necessary funds may be appropriated to complete the main stem to Vandeventer avenue the coming season, as it is a matter of absolute necessity to afford an outlet for the drainage of the western portion of the city, which is being built up very rapidly. And the changes of scenery from rural to urban, although characteristically unlike, tend to revive our memory of the region referred to about Chauteau's Pond. If some romantic old citizen, who, in his boyhood ramblings, enjoyed the rustic scenes of the old creek in its pristine glory,

* The work was planned and executed under the supervision of the City Engineer, and in charge of the Superintendent of Sewers from the beginning, in 1860, up to 1877, when these offices were abolished by the new scheme and charter, since which time it has been under the jurisdiction of the Board of Public Improvements, and under the supervision of the Sewer Commissioner and his assistants.

The terms of these officers were as follows :

1860 to 1867, T. J. Homer, City Engineer : Wm. Wise, Superintendent of Sewers, and M. C. Little, Assistant Superintendent.

1867 to 1871, F. Bischoff, City Engineer ; Wm. Wise, Superintendent of Sewers.

1871 to 1875, J. B. Moulton, City Engineer ; Wm. Wise, Superintendent of Sewers.

1875 to 1876, Walter Katté, City Engineer ; Wm. Wise, Superintendent of Sewers.

1876 to 1877, Chas. Pfeifer, City Engineer; Wm. Wise, Superintendent of Sewers.

1877 to 1881, Robert Moore, Sewer Commissioner ; Wm. Wise, Assistant Sewer Commissioner, and Julius Moulton, Engineer.

1881 to 1883, Wm. Wise, Sewer Commissioner ; Julius Moulton, Assistant Sewer Commissioner, and H. L. Burnet, Engineer.

Since 1883, R. E. McMath, Sewer Commissioner ; Wm. Wise, Assistant Sewer Commissioner, and H. L. Burnet, Engineer.

should now look for some token of its remains, he would find the place covered with railroad tracks, depot buildings and other modern improvements; and in his wanderings would be reminded of the old familiar song:

> "The old mill has gone to decay,
> And the little babbling brook is now dry."

But the brook still lives, though hidden from view and buried beneath the traffic of the busy world. We may imagine a triumphant response from its subterranean prison, in the language of the poet—

> "Men may come and men may go,
> But I go on forever."

ON A CASE OF THE RAPID EXTERIOR CORROSION OF AN IRON WATER-MAIN.

By Philip D. Borden, Jr., and Wm. Ripley Nichols, Members of the Boston Society of Civil Engineers.

[Read April 15, 1885.]

I. STATEMENT OF THE CASE, BY MR. BORDEN.

During the Summer of 1884, unmistakable signs of a leak presented themselves on the line of a six-inch main on the premises of the Fall River Iron Works, situated upon the shore of Mount Hope Bay, where the pressure upon the main was one hundred and twenty pounds per square inch.

On uncovering the pipe it was found that a change had taken place in the material of which it had been composed. The pipe was soft, being easily cut with a knife; was smooth and greasy, having the appearance of plumbago. Investigation proved that six pipes, or seventy-two feet, had been more or less affected. In some places the change extended nearly through the pipe, while at others, but a short distance from the first, the change was much less marked. The inner side of the pipe was perfect as when laid, the coating of "coal-tar varnish" remaining intact. The pipe had been in the ground about nine years.

Following is a section of the specifications relating to the quality of material of which the pipe should be composed, and there has never been any reason to suppose the pipe was not up to the standard as called for.

Quality of Metal.—The metal shall be strong, tough and close-grained, with the carbon combined and not in the form of graphite, and as hard as the case will admit, but not too hard to be readily cut and drilled, and shall be remelted from pigs of gray iron in a cupola or air-furnace, without any admixture of cinder iron or other inferior metal, and shall have a tensile strength of at least 16,000 pounds per square inch."

The accompanying section of the pipe will give an idea of the condition in which it was found, no two sections however would show the same amount of change, while it can readily be seen that it has not been the same on all sides of the pipe, nor has the change followed any rule as to position. In some places it was most on the top of the pipe, as it lay in the ground, in others on one side, again on the other side, and in other places on the bottom.

Although the outside of the pipe was soft when taken out of the

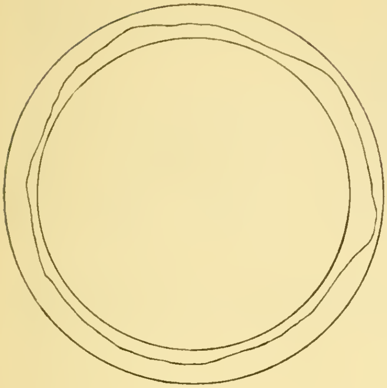


FIG. 1.

ground, it has since become quite hard. On the premises of the Iron Works there are about 800 feet of pipe made and laid apparently under the same circumstances and subject to the same conditions, yet only this piece has undergone the change.

A sluice-way forming an outlet from Crab Pond to Mount Hope Bay is shown by dotted lines, as is one from works of the American Printing Company, through which are discharged the spent liquors from that establishment. Here may appear to be an explanation of the whole matter, but on examining the plan and noting that the pipe was taken out between the points *A* and *B*, neither of which is within one hundred feet of the sluice-way, while the pipe over the sluice-way is intact, it seems as if some other cause would have to be found.

At the northwesterly corner of the nail mill is a point used for at least twenty-five years by a large number of men as a urinal. At first it seemed probable that this might have had some effect upon the pipe, but it is found that a hydrant within five feet of the said corner was not affected. This leads us to suspect this is not the cause sought for.

When the wharf was built the wall was laid up and a portion back of it (shown by dotted lines on the plan) was not filled for several years. Into this pond hole the drip from the rolls of the iron works and the drainage from the wheel pit of the engine was discharged until the hole was filled up and even now it is a question if it is not allowed to discharge there, and find its way to the Bay through the filling, which it could readily do. The fact that this is where the pipe had undergone the greatest change leads us to look at this with some suspicion. The drip from the rolls would, of course, be warm. The main here is a "dead end," intended simply for fire protection. consequently the water might remain therein some time without being renewed, and become quite warm, keeping the pipe in the best condition to be acted upon by salt water. It is conceded hereabout that warm salt water is damaging to cast iron, more especially if oil or other grease is present.

Some years since the condenser of an engine, so located that the tide reached it, was affected the same way, and it was then thought to have been caused by the combined action of heat and salt water. At that time it was stated that the wrought iron, though subjected to the same influences, was not affected.

The whole of this pipe is laid on made land, most of the filling being cinders, iron slag from puddling furnaces, and such other refuse as is usually found about an "iron works." The soil is of such a nature that the water from the bay would readily find its way to, and even beyond,

the pipe, covering it with salt water twice in twenty-four hours, leaving it more or less immersed from six to eight hours out of the twenty-four. One would hardly suppose that with a thickness of but one-eighth of an inch the pipe would stand the pressure of one hundred and twenty pounds per square inch, but such was the case.

An attempt has been made to charge the change to poor material, but of the 56.6 miles of pipe in the city, this is the first and only thing of the kind found. Again, the pipes taken out were not all of one lot. Of the six, one was made by R. D. Wood & Co., three by the Gloucester Iron Works and one by the Warren Foundry and Machine Company. The remaining pipe was so badly broken in taking out that it was not identified.

A plan of the surroundings is here given (on a scale of 200 feet per inch), which may assist in the search for the cause, the effect having already been found.

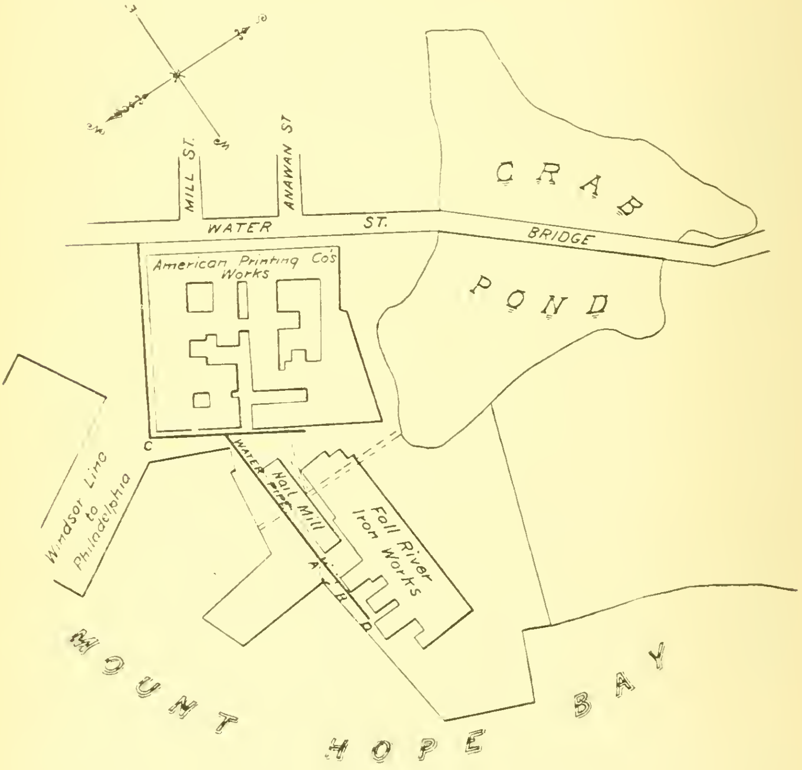


FIG. 2.

II.—CHEMICAL STUDY OF THE CORROSION. BY PROFESSOR NICHOLS.

Some time ago, I received from my colleague, the President of this Society, a specimen of the corroded pipe referred to by Mr. Borden in the earlier part of this paper. Since then I have received other speci-

mens from Mr. Borden, together with samples of the material in which the pipe lay, and other objects which, it was thought, might throw light upon the cause of the corrosion.

The specimen first received by me was a ring cut from a pipe on which the corrosion was very marked. An inspection of the cut surface showed three tolerably well-defined layers: within, a ring of apparently unaltered iron; without, a ring of a brown substance bearing no resemblance to the original iron, being easily cut with a knife and having a greasy feel; between the two, a layer full of black, metallic-looking particles and easily reduced to a brown powder. I speak of these layers as *tolerably* well defined, because, while they appeared distinct on casual observation, closer inspection showed that they ran into each other and could not be separated, one from the next overlying or underlying layer. In other specimens of the pipe only two layers could be made out, the inner apparently unaltered iron, the outer corresponding in character to the middle layer of the specimen first received. The corrosion had not taken place uniformly, so that the bounding surfaces of the layers were not concentric, but a section through the pipe had the appearance indicated in the figure given by Mr. Borden. In some cases, owing to lack of homogeneousness in the pipe, the corrosion assumed the form of pitting, the pits being filled with a material corresponding to the outer layer of the first specimen described. This outer layer, where the corrosion was complete and where no iron remained in the metallic condition, is perhaps the most interesting. It is light brown, almost yellowish in color, but is full of shining black particles. When heated, it gives off some white fumes and the odor of acrolein, glows, and what remains is of a darker color, almost black. The black particles scattered through the mass are somewhat magnetic before and after heating. When the substance is treated with hydrochloric acid it gives off sulphuretted hydrogen gas; the residue is black but becomes white on ignition. The results of the analytical determinations are as follows, the second column merely presenting the statement in slightly different form, calculated from the same data:

	Per cent.	
Moisture	6.62	6.62
Oil, etc., before hydrochloric acid	0.96	0.96
Oil, etc., after hydrochloric acid	0.61	0.61
Sulphur	0.41	....
Sulphur calculated as sulphide of iron	..	1.12
Phosphorus	2.20	....
Phosphorus calculated as phosphoric acid (P_2O_5)	....	5.04
Graphite	14.75	14.75
Non-graphitic carbon	undet.	undet.
Silicon	9.94	....
Silicon calculated as silica ($Si\ O_2$)	....	21.30
Iron	32.73	....
Iron calculated as oxide of iron (Fe_2O_3)*	...	45.74
Copper	0.22	0.22
Manganese	0.53	...
Manganese calculated as oxide (Mn_3O_4)		0.74
Alumina, chromium, lime, magnesia, chlorine, sulphates	traces.	
		97.10

As these figures may meet the eyes of chemists, it is necessary to make a few remarks which will be of more interest to them than to civil engineers. In the first place, no two samples precisely alike could be taken from such a mass, and the results of examinations made by different

* After deducting the amount contained in the sulphide of iron. Calculated as the oxide Fe_3O_4, the amount would be 44.22 per cent.

persons would no doubt vary on this account. The moisture was determined by drying the substance at 110° C., until a practically constant weight was obtained. The "oil, etc., before hydrochloric acid" represents what was extracted by ether from the dried substance. This was dried at 100° C., but a perfectly constant weight could not be obtained. When heated it partly volatilized and partly burned with an odor of acrolein, and left no mineral residue. This oil or grease is partly due to the remains of the coating (coal-tar and linseed oil) with which the pipes were originally covered, and partly, probably, to hydrocarbons in the iron or formed during the corrosion; partly also, in all probability, to oil from the tool used to cut the pipe; but I believe that this is not all. In fact, I found that ether would extract similar oil or grease from the different samples which I had of the slag, or cinder, in which the pipe was bedded, and no doubt this comes from the greasy waste water from the rolling-mill, which, as Mr. Borden says, used to drain into this locality. After treatment with hydrochloric acid, the residue yielded an additional quantity of oil when extracted with ether. This may be due to the presence of an oleate or other fatty salt in the mixture; but oleate of copper or iron were not identified. I propose to study this matter further with another sample which has not been touched with a tool, and which cannot, therefore, have any oil from this source.

The sulphur is present as sulphide of iron, without much doubt. The phosphorus appears to exist to a slight extent, even in the outside layer, as phosphide of iron—mainly, however, as a (basic) phosphate of iron; and I am inclined to think that this compound, which is readily dissolved out by dilute hydrochloric acid, is what gives the brown color to the mass. The carbon is probably there partly as graphite, and partly in the form of carbide of iron, which is formed when gray cast-iron is corroded or dissolved slowly in dilute acids, and to which the formula of FeC_3 has been assigned by Karsten. This would count as graphitic carbon in the analysis. The non-graphitic carbon was not determined, as it would have been impossible to distinguish between that left from the original iron and that due to the protective coating, which is not simply a coating, but is absorbed by the iron.

The silicon is mainly, if not wholly, present in the form of the oxide, silica, but whether it is combined with the oxide of iron forming silicate of iron, or whether the oxide of iron and the silica are simply mixed together mechanically, is a problem which it would be difficult, if not impossible, to solve. The material does not gelatinize with hydrochloric acid, and caustic potash dissolves some of the silica (perhaps about one-half).

The condition in which the iron exists is an unsolved, if not insoluble, problem. Some is there, no doubt, as sulphide, some as phosphide, some as silicide, some as phosphate, perhaps some as silicate. As the material does not precipitate copper from a solution of the sulphate, I do not think there is any metallic iron; as the carbide of iron is magnetic, I do not feel sure of the presence of magnetic oxide, although it is probably there. It was impossible to determine how much iron was in the ferrous condition, on account of the presence of sulphide of iron and of

organic reducing substances. Some of the iron may be in the form of a hydroxide like limonite, and the brown color of the mass may be due to this rather than to a basic phosphate. These conjectures may be taken for what they are worth. If asked to state intelligibly, to one not much versed in chemistry, what the corroded material was, I should say that it is mainly oxide of iron and silica, possibly in combination as silicate of iron, together with some 15 per cent. of graphite or plumbago, some 6½ per cent. of moisture, and some 2 per cent of phosphorus, which is probably there as phosphate of iron, and which corresponds to about 15 per cent. of the phosphate. It having been stated elsewhere that a considerable percentage of alumina exists in the corroded material, I will say that I have been unable to discover more than mere traces.

As to the cause of the very rapid corrosion, various theories have been proposed or have suggested themselves. With reference to the general matter of the corrosion of cast (and wrought) iron in salt (and fresh) water, the classic experiments are those of Mallet, recorded in the British Association Reports for 1838, 1840, and 1843. From his experiments, extending over a period of 387 days, Mallet calculated the amount of corrosion which would take place at the same rate in a century and found * that with different varieties of cast iron the average loss of weight per superficial foot in a century would vary from 11.58 pounds to 16.34 pounds, and the average depth of corrosion from 0.306 inch to 0.431 inch in the same time. This calculation of from three to four tenths of an inch in a century as the depth of corrosion in cast iron, was found to be somewhat low by the examination of guns taken from the wreck of the Edgar, which had been upward of 129 years under water. Here the corrosion was found to be about seven-eights of an inch on the average. Iron from the Royal George was found, after an immersion of 59 years, to be corroded from one-half to three-fourths of an inch in depth.

Mallet found that in foul sea water the corrosion took place more rapidly than in clean sea water, but with nothing like the rapidity of the case before us. His experiments were on specimens of iron wholly and continuously submerged; the alternate exposure to air and sea water, or to water as salt as that at Fall River,† we should expect to cause an increased corrosion, but this certainly cannot be the sole cause here, because beyond the portion of pipe affected there is other pipe which has been likewise alternately exposed and submerged without being corroded. It has been thought that the corrosion has been caused by the material in which the pipe was bedded; that some acid or corrosive substance was developed by the decomposition of the slag, or cinder. Some probability attaches to this view, because cases have been known where steam-pipes have been corroded by the escape of steam into the slag-wool in which they were packed. This Professor Egleston‡ ascribes to the formation of sulphuric acid from the sulphur in the slag-wool. I must confess that I cannot quite see how an acid should be developed under the existing conditions, and I kept for a long time some of the finely-powdered cinder in contact with water taken from the spot, without being able to

* Report of the British Association for the Advancement of Science, x. (1840), p. 299.

† See further on, page 280.

‡ Trans. Am. Soc. Civ. Engrs., XII. (1883), p. 253-261.

discover the development of any acid. I have an experiment in progress which may throw some light upon the matter. In two glass jars I buried small weighed bars of cast-iron (portions of the same casting) in powdered cinder (two different samples), and in another jar buried a piece of the same iron in clean sand. These jars were filled with water from Fall River; every morning the water is drawn off and every evening replaced, so that the iron is alternately covered with water and exposed wet to the action of air. After the experiment had gone on for about four weeks, the pieces of iron were removed, cleaned and weighed. It was found that the iron buried in clean Berkshire sand, and which originally weighed 87.49 grams, had lost 0.15 gram in weight. The pieces buried in the slag weighed the same as at first. I feared the slag might have been too finely powdered, so that the water did not drain away thoroughly, and the experiment is now going on with more coarsely-powdered slag. Meanwhile the water has developed no acid reaction.

Another difficulty in the way of considering the slag as the cause of the trouble is that some of the uncorroded pipe lies in similar material. Mr. Borden sent me three samples of filling from the pipe trench: No. 1, from the west end of the decayed pipe, where the pipe was good; No. 2, from the middle ground, where the pipe was bad; No. 3, from the east end, where the pipe was good. The sample numbered "1" was a clayey gravel, but Nos. 2 and 3 were essentially the same slag, and there seemed no reason why, if No. 2 was corrosive, No. 3 should not be so likewise. Samples of water were also sent at the same time from the three localities. They proved to be alike in their salinity, as appears from the following statement:

	Percentage of— Combined chlorine.	Total solids.
No. 1	1.43	2.86
2	1.48	2.86
3	1.49	2.82

Samples of the three materials in which the pipe was bedded at these different points were then taken and placed in separate beakers, and each covered with water from its own locality. The water was poured off every evening and poured on again every morning, for about a fortnight. The total solid material contained in the water after this treatment was then determined.

	Percentage of total solids.— Originally.	After treatment.
No. 1	2.86	2.96
2	2.86	3.74
3	2.83	3.24

This would also indicate the similarity of the two samples, Nos. 2 and 3.

The cinder in which the pipes are bedded contains a small amount of copper, which might be looked upon as an agent of corrosion. Undoubtedly, if the copper was dissolved out from the slag by the salt water, the iron would be corroded by the solution, and copper would be left on the iron. The amount, however, even in the outside layer, is so trifling that it does not seem as if this could be concerned in the action, and copper occurs in the slag in which the non-corroded pipe lay as well as in that around the corroded pipe.

It is known* that iron structures immersed partly in salt and partly in fresh or brackish water are corroded somewhat rapidly, on account of galvanic action between the portions of iron immersed in the liquids of different densities. It suggested itself that the fresher water draining from the rolling mill might overlie the salter water below, and bring about this condition, but samples of water which were taken for me by Mr. Borden at different stages of the tide, proved to be of essentially the same salinity:

		Total solid matter.
No. I.	Full tide	2.59 per cent.
No. II.	Tide falling, when at top of pipe	2.64
No III.	Tide rising	2.61

It has been further suggested, that the fault was in the original iron; but, as Mr. Borden remarks, this can hardly be the case, as pipes furnished by three different makers were corroded. I procured a piece of the spigot end of one of the pipes, this end being naturally protected from corrosion, and made a partial analysis, which appears in the table below. I have had no experience with the iron generally used for such water mains, but see no reason to suppose the iron at fault.

The most serious part of the problem before us is not to determine why the pipe has corroded, but why it has corroded here so much more rapidly than on either side of the 72 feet length, most of the conditions seeming to be the same. I may say that I have been unable to visit the locality, and it is within the bounds of possibility, although not very likely, that a personal visit might suggest some things which I have not considered. It is also possible that the cause of the corrosion is one that has acted in the past, but is not acting at present. This we cannot know until the new pipe has been longer in position. With what light I have at present, it seems to me most likely that the corrosion is due, not to any one single cause, but rather to a combination of circumstances which happened to work together to produce the observed result. The pipe is bedded in a very porous material, in which, as the water recedes, the air must circulate freely, but which probably retains enough moisture to keep the pipe wet nearly all the time even when not actually covered by water. Now, as Mallet states,† "the conditions the most favorable possible for rapid oxidation of iron consist in its exposure to 'wet and dry,' or to air, covered with a film of water constantly renewed."

Moreover, from Mr. Borden's statement it appears that the temperature is such as to favor chemical action. Mallet found that sea water at a temperature of 115° Fahr. corroded iron rapidly. It is not likely that the Fall River brackish water reaches that temperature, but still the temperature is probably a factor in the matter. When the locality where the pipe lies was being filled, cinders and hot slag (sometimes red-hot) were dumped within from 12 to 15 feet of the pipe, and an iron pipe now carries the hot drip from the rolls over and within 12 inches of this pipe. For five or six years the pipe was used only for fire purposes, and the water was found to be very warm whenever a hydrant was opened. Now, however, the water runs all the time to supply a drinking fountain. It remains to be seen whether corrosion is less active in the future than in the past.

* Mallet, Br. Assoc. Rep., X. (1840), p. 227.

† Br. Assoc. Rep., 1840, p. 256.

It is very possible that the air which comes in contact with the moist pipe is (or was) such as to act upon the pipe more rapidly than ordinary air would. It appears that the locality has been, for a long time, the receptacle of drainage water containing much organic matter, and is even now freely used as a urinal. The decomposing organic matter beneath and in the filling would give rise to carbonic acid and ammonia gases, both of which are corrosive agents.

Whether the air in the interstices of the filling differs from ordinary air, admits, of course, of being ascertained experimentally. At this season of the year, I should not expect as much difference as in summer, when the warmer weather would make the decomposition of the organic matter take place more rapidly. However, I suggested to Mr. Borden a somewhat crude method by which samples of the air might be taken, and on three different days he took samples; those marked "E" are from a point about 15 feet east of the west line of the Nail Mill. Those marked "W" are from a point midway between the points A and B on the plan, where the corrosion was greatest. The results of the examination (for which I am indebted to Mrs. Professor Richards) are as follows:

CARBONIC ACID IN 10,000 VOLS. AIR.

April 1, 1885	E. 4.32 vols.	April 3, 1885	E. 4.94 vols.
	W. 4.99 "		W. 4.89 "
		April 4,	E. 4.15 "
			W. 4.95 "

Outer air usually contains about 3 vols. in 10,000, and ground air usually more than the samples above. The results are not, therefore, very convincing, but I should like to repeat the experiment in warmer weather.

Of the single suggested causes, I have looked with most suspicion upon the "grease" which comes from the rolls of the iron works, and which is evidently present in the slag and probably in the corroded portion of the pipe. Every one of several samples tried showed grease or oil, but as the pipes had been treated with coal tar and linseed oil, I cannot assert that the oily matter found was not derived from this source. It is well known that the greasy water from surface condensers is very corrosive to boilers, and this is partly due to the fact that the grease is decomposed by steam, and fatty acids are formed. I have not yet satisfied myself as to the existence of oleate (or other fatty salt) of iron in the corroded pipe, and this I should expect to find if the grease were the prime cause. I tested also the various samples of water for grease with negative results; but this of itself would prove little, as the samples were all taken the same day. Moreover, it appears that for several years the pipes were exposed to warm and, presumptively, greasy water much more freely than at the present time.

I must confess that one of the most inexplicable things to me is the insufficient protection afforded by the coal-tar coating. Mallet and other experimenters found that coal-tar laid on hot was one of the most protective coatings, and although there are some tubercules in the interior of this pipe, the coating seems to have been well applied. It is hard to believe that, in this case, an unprotected pipe could have decayed much faster.

The accompanying table contains the results of the chemical examination of the three layers of the corroded pipe and also of iron from the spigot end of one of the pipes. As the spigot was not from the iden-

tical pipe from which the corroded ring was cut, the comparison must not be pressed too closely, but it probably represents nearly enough the original iron. We should expect that as the corrosion proceeded, the iron would be partly oxidized and partly dissolved away as protocarbonate or otherwise, and that the carbon, the silicon, the phosphorus would accumulate to form a larger proportion of the mass. Examination of the figures in the table shows that the graphite, the silicon and the phosphorus do increase in amount from the centre outward, and in almost identically the same proportion. It appears, however, that while the iron decreases in the same direction, it decreases much less rapidly.

	Outside layer.		Middle layer.		Inside layer.		Spigot end.	
Moisture...........	....	6.62	....	5.61	....	und.	und.	....
Silicon...........	9.94	....	6.41	....	3.31	....	1.77	....
Silicon calculated as silica (SiO_2).......	....	21.30	....	13.74	....	7.09	....	3.79
Phosphorus	2.20	....	1.44	....	0.69	....	0.39	....
Phosphorus calculated as phosphoric acid (P_2O_5)....	....	5.04	....	3.30	....	1.58	....	0.89
Graphite...........	....	14.75	....	9.46	....	und.	2.63	....
Iron	32.73	....	43.15	....	72.97	....	93.18	....
Iron calculated as oxide (Fe_2O_3)*....	....	45.74	....	60.77	....	....	....	....
Sulphur...........	0.41	....	0.35	....	0.19	....	0.09	....
Sulphur calculated as iron sulphide (FeS)..............	....	1.12	....	0 96	....	0.52	....	0.25
Copper...........	....	0.22	....	trace.	trace.	....	trace.	....
Manganese..........	0.53	....	....	und	und.	....	0.61	....
Manganese calculated as oxide (Mn_3O_4)...........	....	0.74	....	....	....	....	....	....
Oil, etc., before hydrochloric acid...	....	0.96	....	0.03	trace.	....	....	....
Oil, etc., after hydrochloric acid...	....	0.61	....	....	....	....	....	....
Non-graphitic carbon............	....	und.	....	und.	und.	....	0.77	....
		97.10					99.44	

* After deducting the amount required for the sulphide of iron.

Some surprise has been expressed at the lightness of the corroded material, and one chemist has suggested the theory that this may be due to the presence of metallic aluminum. There are several objections to this view. In the first place, it is quite unnecessary. A fragment of the corroded part of the pipe (including the "middle" and "outside" layer, as designated above) was found to have an apparent specific gravity of 2.33, but it was very evident that the lightness was due in part to the fact that the material was very porous and contained, therefore, a good deal of air. Moreover, as it contained oily matter, it was not readily wet by water. Small lumps heated in water to the boiling point and then cooled down gave a specific gravity of 2.73, and when the material was in the form of a moderately fine powder the specific gravity rose to 2 98.

If, now, we take the mean composition of the corroded material (middle and outside layers) to be—

	Per cent.		Per cent.
Moisture	6.11	Oxide of iron	53.25
Silica	17.50	Oil, water of hydration, hydrocarbons, etc	5.83
Sulphide of iron	1.04		
Phosphoric acid	4.17		
Graphite	12.10	Total	100.00

and then reckon the phosphate of iron as corresponding in composition and specific gravity with the native mineral dufreynite, and take as the specific gravities of the other ingredients the observed specific gravities of the corresponding native minerals, we reach the following basis on which to calculate a possible specific gravity for our mixture:

	Per cent.		Sp. gr.
Water, oil, etc	11.94	say 12.0	1.0
Silica	17.50	" 17.5	2.5
Sulphide of iron	1.04	" 1.0	4.7
Graphite	12.10	" 12.0	2.2
Phosphate of iron	15.16	" 15.2	3.2
Oxide of iron	42.26	" 42.3	5.2

The specific gravity of such a mixture as this would be 2.63. This claims to be nothing more than a rough approximation, but it shows that knowing the composition and character of the substance, we need not be surprised at the low specific gravity.

Another reason why I cannot accept the aluminum theory is that, from our knowledge of the difficulty with which aluminum is reduced from its compounds and obtained in the metallic state, I cannot conceive how the reduction could take place when the tendency of all the constituents of the original iron is to become oxidized: No one would claim that this oxidation could be effected in the wet way by the reduction of aluminum compounds.

The third reason for rejecting the aluminum theory is that there is only the merest trace of aluminum present in any form.

Since this paper was read another sample of the corroded material has been submitted to partial analysis. This specimen came from near the bell end of the same pipe, the spigot end of which was taken as a sample of the original iron. The surface here showed the asphalt coating still remaining, and only two layers could be distinguished. The inner layer was not analyzed, but did not seem to be wholly unaltered iron; the outer layer was harder than in the specimen described above, although it could be reduced to a fine powder without difficulty. The results of the partial analysis were as follows:

	Corrosion. Bell end.	Original iron. Spigot end.
Moisture	3.87	Undet.
Oil, etc., extracted by ether	0.40	Trace.
Oil, etc., after hydrochloric acid	0.22	0.00
Iron	52.94	93.18
Graphite	7.93	2.63

THE WATER SUPPLY OF CLEVELAND.

ITS SANITARY AND CHEMICAL QUALITIES.

By N. B. Wood, Member of the Civil Engineers' Club of Cleveland.

[Read November 11, 1884.]

In these days, when man from sordid motives, contaminates or adulterates the necessities of life, when accidentally or carelessly he accomplishes it, or when it is impossible for him to avoid doing so, it becomes

a matter of importance to all to study the effects of such contamination, to prevent it if possible, and to avoid the use of the contaminated article when practicable.

The water supply of Cleveland is obtained from four sources—the lake chiefly, the river, the springs and wells, and the clouds. We have been in the habit of extolling the water delivered to us by our city waterworks. We have often seen it stated by our city press that we have the purest water in the world, and, as a consequence, have the healthiest city in the world, all of which has about as much foundation in fact as the assertion that we have the best fire-engines in the world. There is no doubt that while the water supplied to our city is much purer than that supplied to many other cities, it is far less pure than it should be.

There is no doubt that much of our valuable water supply has gone into disuse, either from having been officially condemned, or from the mistaken or preconceived notion of the people that it is unfit for use. These preconceived opinions with regard to the fitness or unfitness of it are very excusable, and, in the main, should rather be encouraged than discouraged. Water from any source should be looked upon with suspicion until decided by competent examination to be of a nature *not likely to be dangerous.* This cautious wording is necessary because contaminated water is a poison of such an insidious nature that no examination, however thorough, or however scientifically conducted, can determine the particular dangerous component part of such water. According to Prof. Frankland and other eminent authorities, chemical analysis cannot determine whether water is infectious or not. Prof. Frankland says: "The presence of an infectious quality in water cannot be proved by chemical analysis, and is only learned, too late, by its effects on man. But though chemistry cannot prove any existing infectious quality, it can prove, if existing, certain degrees of sewage contamination, and every sewage contamination which chemistry can trace ought, *prima facie,* to be held to include the possibility of infectious properties." Notwithstanding all this, there are certain phenomena observable during the chemical examination which furnish valuable data upon which to base an opinion relative to the merits of water for domestic and dietetic purposes. For instance, a sample of water, which, though evaporating to dryness with a scarcely perceptible residue, gives off the characteristic odor of urine while evaporating, would be immediately condemned as unwholesome.

The conclusions arrived at by the writer and recorded in this essay, are the results of an extended set of experiments, which were inaugurated primarily for the purpose of determining the fitness of the water he was obliged to drink. This water is obtained from a spring which issues from a bank on which stands a row of outhouses not more than thirty or forty feet vertically above the stratum from which it issues. The results of these experiments were so surprising to him, that he extended them so as to demonstrate whether this spring is an exception or a rule as to quality of water obtainable from springs in this city.

The following is a general outline of the work done: Commencing with a spring which is located near the west end of the old river bed,

and ending with one which issues from the hillside between Herschel street and Central Way, seven springs have been examined, which are supposed to give a fair average of the spring water, and *perhaps* the well water obtainable west of the river. Compared with these results, one analysis of lake water taken from service pipe and one of river water taken from it at the C.; C., C. & I. Ry. freight bridge, will be found in the table subjoined.

It must be borne in mind that no attempt has been made at absolute quantitative accuracy in these analyses; but the figures given will be found substantially correct as far as they go, and sufficiently in detail to answer the purpose for which they were made. Such experiments, in order to be complete, must of necessity be expensive in apparatus and time, neither of which the writer has an unlimited command of. No attempt was made to determine the quantity of organic matter present, except in the lake and river waters, but comparative tests were made of all with permanganate of potash, which, though giving no positively reliable results, does give negatively reliable ones. By this, I mean that if a sample of water be treated with a dilute solution of permanganate of potash until it has a faint pink tint and stands several hours without losing its color, the water may be considered free of organic matter. If, on the other hand, it loses its color, the sample may or may not contain organic matter. None of the samples tested gave any marked reaction when tested for organic matter by this method, except those from the Herschel street spring and from the old river bed, which represent the extremes tested. One of these showed a greater (Herschel street) and the other a less decolorizing power than lake water. We may with confidence, then, assert that six-sevenths of the spring water has less organic matter in it than our so-called pure lake water. The further discussion of the properties and peculiarities of the water from these various sources will be continued after the following:

TABLE OF ANALYSES.

Place where Water was obtained.	Total solid content, grains per gal.	Chlorides, nitrates, nitrates sol. in alcohol.	Sulphates (Lime).	Carbonates, Lime and Mag.	Silica.	Organic matter.	Organic matter by Permanganate.
Spring near end of old river bed	41.00	10.40	14.00	16.60	......	......	Trace.
Spring on West River street	54.04	17.09	11.09	25.55	.. ..	......	None.
Spring on South of Fairfield, near Scranton	31.60	8.00	10.60	13.00	......	......	None.
Spring North of Fairfield street, near Scranton.	28.60	7.00	6.80	14.80	... ..	......	None.
Spring under Nickel Plate Ry. bridge	26.40	......	......	......	... .	......	None.
Spring rear of N. Y., P. & O. Ry. shops...	62.00	17.20	15.00	29.80	.....	......	None.
Spring between Herschel street and Central Way....	45.50	17.60	12.00	15.90	.....	... .	Much more than lake water.
Lake water from service pipe..	9.11	0.82	3.01	3.40	0.65	1.22	
River water	18.05	......	......	......	......	5.04	Residue red after ignition, indicating much iron

These analyses show a greater variation in the "total solid contents" than would be supposed could possibly exist, since the springs all issue from about the same depth, except that near Herschel street, which has peculiar properties which I shall refer to further on. They all run out of a bank, composed of alternate strata of sand, clay, and gravel, at a depth of about sixty feet. The sand is calcareous, being composed, to some extent, of rounded grains of carbonate of lime. The last stratum of clay over which the water runs, and which is impervious, is of the blue variety, much impregnated with organic matter; and above this is a stratum of quicksand, also containing much organic matter, through which the water filters.

With the exception of the sample from Herschel street, the inorganic portion of the solid contents is nearly the same in quality. The water is all excessively hard with both permanent and temporary hardness. Two of the springs yield water which *might* be considered unwholesome on this account, but both yield water which rivals the purest distilled in transparency and freedom from suspended particles, and permanganate solution finds nothing in it for which it is willing to change color.

The Herschel street spring, which is the largest of all, flowing several gallons per minute, seems to be of quite a different character. It springs from the bank much higher up, and the adjacent table-land is much lower than other parts of the city, being what was known as "the old camp ground." This spring, then, is not more than fifteen feet below the surface. Its water holds large quantities of nitrites and chloride of sodium in solution, which according to eminent authority denotes what is termed previous sewage or animal contamination. As this term is somewhat blind, but of general use, it may be pardonable to digress sufficiently to explain it. When sewage, or other nitrogenous animal matter in solution, is filtered through a sufficient depth of soil, the oxygen of the air attacks the carbon, converting it into carbonic acid; at the same time it converts the nitrogen into nitrous or nitric acids, which combine with whatever bases may be at hand to form nitrites or nitrates. The water after being thus filtered may contain no trace of organic matter, but it is assumed that the presence of nitrites or nitrates is evidence of former contamination to at least the extent of the nitrogen present as compared with the same amount of nitrogen in sewage. It is evident that this cannot always be true, since nitrates are known to exist in large quantities in places where sewage contamination could not occur. It is evident, however, that when only nitrates are present, the decomposition has been so complete that no fears need be entertained with regard to the purity of the water, or its fitness for any dietetic purpose. Our chemical investigations, then, teach us that with the exception of the Herschel street spring, which is very bad, and the "old river bed," which is objectionable, our spring water is of most excellent quality for domestic use, and this conclusion is in harmony with that of Prof. Frankland, who says: "Of all the different varieties of potable waters, the best for dietetic purposes are *spring* and *deep well* waters. They contain the least proportion of organic matter, and are almost always palatable and wholesome. Such waters are of inestimable value to communities, and their conservation and utilization are worthy of the greatest efforts of those who have the public health under their charge."

I need only refer to the river water casually. Its composition as water is of little interest; its large percentage of organic matter does not strike us with surprise, for we know the river to be nothing less than a festering cesspool; a stagnant, loathsome receptacle of sewage and chemical by-products, which occasionally spills over and pollutes our outer harbor and our principal water supply, the lake. We have already had very able papers read before this society treating upon this very important subject of river pollution. The subject ought to be discussed publicly, so that public action might follow to remove or prevent this lamentable state of our river; as it will, no doubt, have a greater effect on the health of the people in times of epidemic than all other causes combined.

By referring to the table, we find that the lake water delivered to us through the city water-works is far superior to all others in respect to the "total solid contents," which is less than ten grains per gallon. This for all technical purposes (except, perhaps, the making of beer) places it far in advance of anything obtainable here except rain water; but even in this respect it is inferior to the water supplied to Jamestown, N. Y., or to Detroit, and many other places. The principal objection, however, to the water is to its use for domestic purposes. It is not what might be called bad, but it is far from being as good as we could wish. The *quantity* of organic matter which it contains is quite large. On this point all chemists agree, varying from that given in the table, 1.22 grains per gallon, to 2.65 by another analyst. It probably varies much under different circumstances, such as changing of winds and seasons, *et cætera*. But the *quality* of this organic filth is the objectionable feature of our city water. No doubt much of it is of the same character as that usually found in lake and river waters, and due to the decomposing vegetable matter, but *some* if not *much* is due to contamination by sewage, shipping and river pollution of various kinds. Our water often tastes of "coal oil," and no one doubts for a moment where it comes from. The river water has been served up to us to make our tea and coffee with. If we allow lake water to stand in a tank, we find a thick coating of slime collects upon its sides. This is the mycelium from which fungi may develop. None except water contaminated by organic matter ever can produce this growth. In this respect, it might be of interest to compare the phenomena observed under similar circumstances in the other samples of water. The springs at Herschel street and "old river bed" develop similar slimy substances; but the other springs after long standing and depositing the carbonate of lime, produced a growth of innoxious, one-celled chlorophyl-colored plants. The growth was small, but quite apparent on account of its color. This brings us to another interesting part of this intricate subject, namely: Although this water gave no indication of the presence of organic matter by any chemical test, it evidently *did* contain *some*, for the germs or spores of these plants must surely have been present. No fungoid growth ever appeared. Rain water, collected upon a porcelain dish after it had been raining a few minutes, subjected to the same test, remained perfectly pure, having neither color, odor nor sediment after months had elapsed, indicating that any taint possessed by such water is due to organic and other impurities from the roof upon which it was collected. But dew

collected by the same means, to the amount of several ounces, produced mycelium in a short time, though evidently not of the same variety as those previously mentioned.

What conclusions are we to draw from this rather conflicting mass of evidence? The general impression is in favor of spring water for dietetic purposes; and provided it has been *proved* by *competent* examination to be good, no doubt this conclusion is the correct one. But, as our own table shows no two springs (no matter how close together) can be relied upon for similar water, we must look on them with suspicion until we know their quality. On the other hand, our city water supply varies from day to day; now river water and again deep lake water; now clear as crystal and then muddy; but at the best we know it contains the foulest organic matter which has had no opportunity to decompose. The water supply should be taken from a greater distance from the shore. The sewage of the city should be carefully excluded from the river, and either used for irrigating the land or emptied into the lake so far toward the east that no possible contamination can occur, and no vessel should be allowed to discharge any filth for several miles above the city. If there be any foundation for the germ theory of disease, the dejections from a single cholera patient cast into the lake near the crib would be sufficient to poison the whole city with the infection. Would it not be better, then, in case of a visitation of this kind, to either abstain from using the lake water or never to use it except after having been boiled?

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

APRIL 15, 1885 :—The Club was called to order by President Moore, at the Mercantile Library, twenty-four members being present.

The minutes of the previous meeting were read and approved.

The Executive Committee reported a letter from C. W. Bullen, Chairman of House Committee of Mercantile Club, in regard to the use of their rooms.

On motion of Col. Moore, the Club expressed their thanks to the Mercantile Club for the use of their rooms for the past year.

Moved by Mr. Ockerson : that the Club hold their meetings at Washington University. This motion was laid over until next meeting.

Mr. Wm. W. Penney was proposed for membership by S. B. Russell and Thos. D. Miller.

Mr. H. W. Baker read a paper on "Steamboat Shafts."

A general discussion followed.

[*Adjourned.*] THOS. D. MILLER, Secretary.

APRIL 29, 1885 :—The Club was called to order by President Moore, at the Mercantile Library, twenty-four members being present.

The minutes of last meeting were read and approved.

The Executive Committee reported that the resignation of Mr. John A. Sobolewski had been received and accepted.

The Committee reported favorably on the proposals for membership of Wm. W. Penney and O. A. Orrman. They were balloted for and declared elected.

Mr. Ockerson's motion to hold the meetings of the Club at Washington University was taken up and carried.

Mr. M. L. Holman read a paper, "House to House Inspection to Prevent Water Waste."

The paper was generally discussed.

Mr. C. F. White read a paper on "Dynamometers."

After a discussion of the paper the meeting adjourned.

THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

APRIL 21, 1885 :—The 207th meeting was held in room 25 Honore Building, at 4 P. M. President Williams in the chair.

In the absence of the Secretary, Mr. Liljencrantz was appointed to act as Secretary pro tem.

The minutes of the preceding meeting were read and approved.

Mr. Artingstall, for Committee on Topics, submitted report as amended. On motion this was accepted and adopted.

In response to request at the last meeting, Mr. Zellweger offered the following suggestions :

1. To establish a question box, into which any member may deposit clearly defined questions (signed by the inquirer, and dated).

2. To take up the questions one by one in the order of their dates, by submitting them to the Report Committee, who may answer them immediately or prepare an

answer for the next meeting. In case of absence of such Committee, the question to be sent to him by the Secretary.

3. To answer the questions in writing, in a condensed form, for preservation.

It was voted that the request be continued to the next meeting.

President Williams, for the Committee on Quarters, announced that arrangements had been made with the manager of "The Permanent Exhibit of Building Materials" for quarters in their apartments on very favorable terms, and that the effects of the Society had been transferred thither.

On motion of Gen. Fitz Simons, the report and action of the Committee were ratified.

The Secretary read a letter from the Secretary of the 'Liverpool Engineering Society' in regard to exchange of transactions.

After an interesting discussion on Dredging, the meeting adjourned.

G. A. M. LILJENCRANTZ, Secretary pro tem.

MAY 5, 1885:—The 208th meeting was held in the Society's Hall, at 4 P. M.

In the absence of the President Mr. Artingstall was called to the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a member was presented from Mr. Julius Merriam Howells, City Engineer, Richmond, Ind., indorsed by Messrs. B. Williams, MacRitchie and MacHarg.

The Secretary reported receipt of photograph likeness from Mr. J. J. McVean.

The Secretary read a letter from Mr. H. G. Prout, Secretary of the Association, to the effect that members could obtain from him any books on the catalogue of John Wiley & Sons at 25 per cent. discount, postage paid; on account of advertising in the JOURNAL.

It was voted that a bill from the Association of Engineering Societies for $1 on each copy of the JOURNAL taken by the Society be paid; amount $108.

It was voted that the report of the Committee on Topics, adopted at the last meeting, be printed in the JOURNAL.

Mr. Wright read a paper, "The Best Material for Street Railroad Rails."

[*Adjourned*]. L. P. MOREHOUSE, Secretary.

The Members of the Western Society of Engineers are invited to send communications of a complete and comprehensive character, on any of the subjects included in the following list, as well as on other analogous questions :

Sewers for suburban districts.
Water supply for suburban districts.
Pollution of domestic water supply.
Waste of water, prevention of.
Pumping machinery of water works.
Dredging and dredging machinery.
Steam excavators.
Pile foundations.
Foundations under water.
Docks and harbors.
Removing snow blockades.
Mining in Western States.
Mining in Lake Superior regions.
Mining machinery and appliances.
Blasting in streets of cities.
Blasting under water.
Floods in Western rivers.
River improvements.
Railway signals.
Highway bridges over navigable streams.
Street pavements of Chicago.
Street cleaning machines, etc.
Handling and storage of grain.
Gaseous fuel.
Use of steel for structural purposes.
Qualities of Portland and natural cement.
Mechanical power on street railways, steam, electricity, cables, etc.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

APRIL 6, 1885:—The meeting was called to order by Mr. Rundlett, President.

There were present eleven members and two visitors.

A letter was read from Sec. H. S. Treherne of the Architectural Association of Minnesota, inviting members of the Civil Engineers' Society of St. Paul to become associate members of that association. On motion the letter was referred to the Board of Directors.

Mr. W. S. Truesdale read a paper on the Building Stone of Minnesota, which was recommended for publication in the JOURNAL.

Mr. J. L. Gillespie read a paper on the Improvement of the Upper Mississippi, after which opportunity was given for discussion and the examination of maps, plans, etc.

The applications of Mr. F. T. Hampton and Mr. John Grondal for membership having been duly approved, ballots were taken and both were declared elected, and the Secretary was instructed so to notify them.

The subject of Mr. Chas. F. Loweth's question, viz., "Where are the advantages and disadvantages of using Steel for Structural Purposes—generally speaking, is it desirable to use steel for that purpose at present?" was then taken up for discussion. The members present not having had time to investigate the subject as much as they would have liked, the question was laid over to the next meeting.

The meeting then adjourned to the first Monday in May.

C. J. A. MORRIS, Secretary.

MAY 4, 1885 :—A regular monthly meeting was held at 8 o'clock P. M., Mr. L. W. Rundlett, President, presiding. There were present 13 members and 4 visitors.

The application for membership of Mr. Philip Buehner, Mr. John B. Parkinson, Mr. Andrew W. Munster and Mr. Albert R. Starkey having been approved by the Board of Directors, ballots were taken and all were duly elected. The Secretary was directed to notify them of same.

A letter was then read by the Secretary from Mr. H. G. Prout, Secretary of the Association of Engineering Societies, conveying the information that he would furnish members of the St. Paul Society any books on the catalogue of John Wiley & Sons at 25 per cent. discount from the catalogue prices, on account of advertising in the JOURNAL.

The Secretary read the report of the directors on the subject of Mr. H. S. Treherne's letter of April 2, relating to the members of the St. Paul Society becoming associate members of the Architectural Association of Minnesota, the substance of which was "that they did not recommend any action of the St. Paul Society, but approved of a membership in the Association, as suggested by Secretary Treherne in his letter." On motion the report was accepted.

Mr. W. S. Morton then read a paper on the subject of the Falls of St. Anthony, giving a description of the principal engineering work that has been done there for its preservation and utilization, and an opinion of what seemed necessary yet to be done to fully accomplish the end sought by the construction of the United States concrete dike and timber apron on the face of the Falls. Mr. Morton's paper was listened to with great attention, and when read, was followed by Mr. H. E. Stevens, who read a report which was made in 1882, to the Minneapolis Mill Co., by J. L. Gillespie, Mr. Joseph Frizell and himself, on the possibility of lowering the tail race of the Washburn B Mill, after which followed a lengthy discussion on the subject of the papers.

The Committee on Constitution and By-Laws not having been able to prepare a report, were relieved from further duty, and the Secretary was appointed such committee, with power to draw up and submit for adoption a Constitution and By-Laws that in his opinion seemed best for the Society.

On motion of Mr. Morton, the Librarian was authorized to purchase a book-case for books now on hand.

On motion it was decided not to take up the question of "Steel, and its uses for structural purposes" until next meeting, on account of the length of time already spent. The meeting then adjourned to the first Monday in June.

C. J. A. MORRIS, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE THEORY OF CAR-STARTERS;

OR, THE MECHANICAL STORAGE OF THE ENERGY LOST IN THE STOPPING OF A STREET CAR.

BY J. B. JOHNSON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read March 18, 1885.]

INTRODUCTION.

The object of this paper is to discuss some of the fundamental requirements that must be fulfilled in the storage of the energy of a moving car, to show the utter impracticability of the usual devices designed for this purpose, and to point the way to a possible solution. I shall also give the methods of analysis and some of the most useful general equations involved, together with a discussion of the resilience of steel under uniform bending stress.

The car-starter is a modern engineering device, designed in the interest of that beneficent society with the alphabet title, being to the sanguine and ingenious mechanic as fertile in its promises and as barren in its results as the perpetual motion. The mechanical difficulties, such as the necessary connections, controlling and reversing gear, have been satisfactorily solved, and many industrious and ingenious men have felt that success was assured, when, on applying their device to a full-sized, loaded car, a common fate has come to all. *The spring breaks!* Not baffled by this failure, our persistent friend thinks he has but to get a stronger spring, when all will go well. Alas, he has started for the pot of gold at the end of the rainbow! For we propose to show that no steel spring that may ever be attached to an ordinary street car can absorb the energy of that car when loaded with people and moving at the rate of six miles an hour.

There are probably few thoughtful engineers or mechanics who have not pondered on this question. When one sees the driver vigorously applying the brake to a moving car in order to destroy, or burn up, the energy which the exhausted team have imparted to it, and when these much-abused animals are then called upon immediately to replace this energy which the driver has willfully destroyed, one fancies a dreary

protest on the part of the brutes against this reckless waste of their precious strength. For certainly, if the energy lost in stopping a car could be stored and utilized in starting it again, then the team spends no more energy than if they go straight ahead and never stop. I have seen but one device that was designed to accomplish this desirable end, and that was the invention of a Mr. Brown, of Chicago, and was shown at the Railway Exhibition held in that city two years ago. It had not been out long enough to have its efficiency tested on the ordinary street car, but the model was of full size, and the appliance worked to perfection.* The energy was stored in a coiled steel spring worked about one axle, and the uncoiling of this spring was to start the car. I took great interest in the device, for I had not been without notions on the subject myself, and it seemed to me this man had satisfactorily solved the problem. When he came to apply it to a loaded car, however, it went the way of all car-starters; that is, the springs broke before the car was stopped. When last heard from my friend was looking after a stronger spring. I think I will be able to show that a spring large enough to do this work must weigh not less than 3,400 pounds, and the series of trials will probably be a very long one before a spring of this size will be tried. It will also be shown that the special cross-section and length of the spring is of no consequence so long as the *form* of cross-section remains the same. That is, if the cross-section is rectangular, it requires a given *volume* of steel to store a given number of foot-pounds of energy, for a given kind of stress, whatever the length, width, and depth. This volume will be found to vary, however, when the form of the cross-section changes, as to that of a circle, for instance, and also when the character of the stress changes, as from bending to torsion, or to direct stress, either tension or compression.

DISCUSSION.

Energy may be stored in an elastic solid, as steel, in three ways: 1. By direct tension or compression, producing longitudinal distortion; 2. By bending, producing lateral distortion; 3. By torsion, producing circumferential distortion. In this discussion we shall assume the energy to be stored by the second method in a coiled spring, the distortion consisting in a further bending or straightening of the coil, thus changing its radius of curvature and introducing simply a uniform bending stress in the spring.

Let W = weight in lbs. of loaded car, including weight of spring.

Let v = velocity of car in feet per second.

Then the energy of the moving car in foot lbs. is $\frac{Wv^2}{64}$.

If the car be supposed to be moving on a down grade such that the effect of the grade is just sufficient to overcome the resistance to motion, then to stop the car we must do $\frac{Wv^2}{64}$ foot-pounds of work. If this work be exerted by a steel spring, coiled on the car axle, for instance, then the movable end of the spring must pass over a distance D under an average pull P_a, such that

$$P_a D = \frac{W v^2}{64}. \qquad (1)$$

* Here the working of this special design was shown by a blackboard drawing.

Since the resistance of the spring is zero when it first begins to act, the maximum force of the spring will be $2\,P_a = P_m$.

$$\therefore\ P_a\,D = \frac{W\,v^2}{64} = \frac{P_m\,D}{2},\ \text{or}$$

$$P_m\,D = \frac{W\,v^2}{32}. \qquad (2)$$

The resistance of a coiled spring to a circumferential force at right angles to the axis of the coil is simply its resistance to bending from its normal, coiled condition. Therefore, when such a spring is further bent, or straightened, by forces acting in a plane perpendicular to its axis, it causes a bending moment, M, acting in this plane, and this is held in equilibrium by the moment of resistance, M_o, of the spring. Hence we have $M = M_o$.

For a spring of uniform rectangular section, its moment of resistance is

$$M_o = \frac{1}{6} f\,w\,t^2 \text{ where}$$

f = stress per sq. in. in extreme fibre ;
w = width of cross-section,
t = thickness of " "

Also, the maximum bending moment

$$M_m = P_m\,v, \text{ where}$$

P_m = maximum circumferential force applied to one end, and r = the radius of the coil.

$$\therefore\ M_m = P_m\,r = \frac{f\,w\,t^2}{6}. \qquad (3)$$

From eq. (1) we have

$$D = \frac{W\,v^2}{64\,P_a},$$

which gives us the *distance* through which the movable end must be carried, in order to stop the car or to absorb all its energy. But since D is measured around on the circumference of the coil, the angular amount of this motion, expressed in complete revolutions, is

$$\alpha = \frac{D}{2\,\pi\,r},\ \text{or}$$

$$D = 2\,\pi\,r\,\alpha, \qquad (4)$$

where α is the total angular movement of the movable end of the spring, or it is the *total angular deflection* in the entire spring. Now,

$$d\,\alpha = \frac{M}{E\,I}\,d\,s \qquad (5)$$

where

S = length of arc = length of spring in this case.
E = modulus of elasticity of the materials.
I = moment of inertia of the cross-section.

Integrating (5) we have

$$\alpha = \frac{M}{E\,I}\int_o^l d\,s = \frac{M\,l}{E\,I} \qquad (6)$$

where α is given in terms of r.

If we wish α in revolutions, we have:

$$\alpha = \frac{M\,l}{2\,\pi\,E\,I} \qquad (7)$$

From (3) we have:

$$M = \frac{f\,w\,t^2}{6}.$$

$$\therefore\ \alpha = \frac{f\,w\,t^2\,l}{12\,\pi\,E\,I} \tag{8}$$

Since, for rectangular cross-sections, $I = \frac{1}{12}\,wt^3$, we have:

$$\alpha = \frac{f\,l}{\pi\,E\,t} \tag{9}$$

Combining equations (9) and (4), we have:

$$\frac{D}{2\,\pi\,r} = \frac{f\,l}{\pi\,E\,t} \text{ whence}$$

$$D = \frac{2\,f\,l\,v}{E\,t} \text{ in inches} \tag{10}$$

Combining (10) with (1), we have:

$$\left.\begin{aligned} \tfrac{1}{12}\left(\frac{W\,v^2}{64}\right) &= \frac{2\,P_a\,f\,l\,v}{E\,t} \\ \text{or from (2)} \quad \tfrac{1}{12}\left(\frac{W\,v^2}{64}\right) &= \frac{P_m\,f\,l\,v}{E\,t} \end{aligned}\right\} \tag{11}$$

Where the energy is expressed in inch-pounds, v being expressed in inches per second.

From (11) and (3):

$$\tfrac{1}{12}\left(\frac{W\,v^2}{64}\right) = \frac{f^{\,2}}{6\,E}\,w\,t\,l \tag{12}$$

all in inch-pounds, for rectangular section.

The left member of eq. (12) is the energy absorbed and the right the measure of this energy in terms of the volume of the spring and the stress on the extreme fibres. If we wish this in terms of the weight of the spring and in foot-pounds, we divide by 12 and substitute the value of the weight, which is

$$W' = \frac{w\,t\,l}{3\,6};$$

whence the energy that the spring may absorb is

$$G = \frac{f^2}{20\,E}\,W' \text{ in foot-pounds.} \tag{13}$$

If $f = 60{,}000$, and $E = 30{,}000{,}000$, we have

$$G = 6\,W';$$

or, but 6 foot-pounds of energy can be stored in 1 pound of steel spring, when the extreme fibres have a computed stress of 60,000 pounds per square inch.

If the stress on the extreme fibre may be 120,000 pounds, then one pound of steel will store 24 pounds of energy, and if a spring may be strained to 240,000 pounds on the extreme fibres, then one pound of the spring will store 96 foot-pounds of energy. It has been found from experiment that small springs, such as are used for clocks, may be strained to this amount without injury, but it is not probable that large s rings could be made of any such strength. I have therefore limited this discussion to a stress on the extreme fibres of 60,000 pounds per square inch. The Watertown experiments on steel springs show that the best-tempered steel 1 inch thick may have an elastic limit as high as 120,000 pounds per

square inch. If this stress be allowed, the weight of spring required would be one-fourth that taken in this paper.

For a spiral spring of round section, eq. (12) takes the form—

$$\text{Energy stored} = \frac{f_2}{8\,E}\,\pi\, r_1{}^2\, l,$$

where $\pi\ r_1{}^2 l$ represents the volume of the spring whence we see that a round spring will absorb by bending only $\frac{3}{4}$ as much energy as a spring of rectangular cross-section.

Since the energy stored is always proportioned to the volume of the spring, we see that the special dimensions are not significant so long as the volume and form of cross-section remain the same. We need not make a special discussion, therefore, for various cross-sections, but can discuss for volume or weight alone. This simplifies the question very much. It may be said, in passing, that this principle holds in all cases of resilience; the dimensions may vary at will, but so long as the volume and form of section remain constant, the energy that may be absorbed is constant. It only is necessary to find the modulus for different forms of cross-section and for different kinds of stresses.

We are now prepared to compute the weight of a steel spring designed to store a given amount of energy, when the spring is coiled, and when the energy is stored by inducing a bending stress.

For steel, let f be taken as 60,000 lbs. per sq. in.

Let $E = 30{,}000{,}000$.

Then we have, for any steel spring, strained as above:

$$G = \tfrac{1}{12}\left(\frac{Wv^2}{64}\right) = 72\,W',$$

where the left member is the energy of the moving car in inch-pounds.

$$\text{Whence } Wv^2 = 55{,}300\ W' \tag{14}$$

for steel under uniform bending stress of rectangular cross-section, giving a computed stress on the extreme fibres of 60,000 pounds per square inch.

Now, W includes the car and passengers, which we may call W'', and also the weight of the spring, or W', or

$$W = W' + W'',$$

and we have

$$(W' + W'')\, v^2 = 55{,}300\ W',$$

or

$$W' = \left(\frac{v^2}{55{,}300 - v^2}\right) W'', \tag{15}$$

where v is in inches per second.

From eq. (15) we have:

When the velocity of the car is less than the square root of 55,300, or less than 20 feet per second, or than 13.6 miles per hour, the weight of car and passengers, W'', may have a finite value, but as the velocity approaches this limit, W'' diminishes, and when the velocity has reached this limit the weight of the spring is infinite for any finite value of W''. If now W'' is also zero, then W' is indeterminate; that is, at this velocity, if the total moving load is the weight of the spring alone, it may just store the energy due to its own motion, whatever its size. When its velocity is greater than this it could not store the energy due to its own weight, since W'' or the additional load now becomes negative.

If we now take the case of a St. Louis car, weighing 4,600 pounds, loaded with 65 passengers (a daily maximum on one line), weighing 9,100 pounds, or a total of 13,700 pounds, we obtain from eq. (15) for W' a value of 3,400 pounds, or a steel spring under bending stress of sufficient size to store the energy of this loaded car on a down grade just sufficient to overcome the frictional resistances, weighs *a ton and a half*, or it contains *seven cubic feet of metal*. It is very obvious that no such spring ever would or could be attached to a common horse-car. For the sake, however, of showing the utility of the equations that have been developed, we will proceed to proportion such a spring to meet certain requirements.

Three lines of investigation are now open to us :

1. We may determine a coil of a given radius and length which will absorb all the energy of the moving car, and compute the thickness of the section.

2. We may determine a spring which will absorb the energy of the car without causing the wheels to slide, and find its cross-section and length.

3. We may take a spring of practicable size and shape, and so dimension it as to just come to its maximum working stress when the wheels are made to slide.

Each of these will be discussed.

1. Suppose the coil may be 15 inches in diameter (centre to centre of opposite sections) and 50 inches long. Then its superficial area will be about 2,000 square inches when due allowance is made for spacing between sections. Since the weight of this spring must be 3,400 pounds, its volume is 12,240 cubic inches ; therefore our spring must be about *six inches thick*.

To coil such a spring is of course impossible; but if this could be done, what would the stress on the connections be when this spring is wound up?

From eq. (10) we have—

$$D = \frac{2\,f\,l\,r}{E\,t} = 8 \text{ inches},$$

as the distance through which the movable end of the spring will move with reference to the fixed end.

To find what the pull is on the end of the spring when wound up, we have—

$$\text{Energy stored} = \tfrac{1}{12}\left(\frac{W'v^2}{64}\right) = 245{,}000 \text{ inch-pounds}.$$

But this is equal to the average pull on the spring into the distance moved over, and since the maximum pull is twice the mean pull, we have—

$$\frac{P_m\,D}{2} = 245{,}000 \text{ inch-pounds},$$

$$\text{or } P_m = 61{,}000 \text{ pounds},$$

as the maximum pull of the spring when the car stops. This is a circumferential force acting with a radius of $7\frac{1}{2}$ inches, and hence its turning moment is 457,000 inch-pounds. But is it possible to have so large a turning moment exerted on our axle without its causing the wheels to slip?

If the radius of the car wheel is, say, 15 inches, if the maximum load on one axle is 8,500 pounds, and if the coefficient of friction be taken as one-half, as it may be on street tracks, then the wheels will slip under a moment of 63,700 inch-pounds, or about 14 per cent. of the moment found necessary to store the energy of the car with the spring as here computed. This new limitation leads us to the discussion of the second case.

2. To store the energy of the car without causing the wheels to slip, what shall be the dimensions of the spring?

Since the maximum moment that can be exerted on one axle is found to be 63,700 inch-pounds, we have $P_m r = 63{,}700$, where r is the radius of the coiled spring. If this be taken as $7\frac{1}{2}$ inches, as before, then $P_m =$ 8,500 pounds.

But $\frac{P_m D}{2}$ must equal the energy of the car, or 245,000 inch-pounds; whence,

$$D = 58 \text{ inches.}$$

From eq. (10)

$$D = \frac{2 f l r}{E t}$$

Where all is now known except l and t, evidently either can be chosen at pleasure. If $t = 1\frac{1}{4}$ inches, then l must be 2,700 inches = 225 feet long. The width of the section is yet to be found.

From eq. (3) we have—

$$w = \frac{6 P_m r}{f t^2} = 3 \text{ inches.}$$

If now this spring be coiled as closely as possible with a $7\frac{1}{2}$-inch radius, it would make a coil 180 inches or 15 feet long. One end of the coil would move through a distance of 58 inches with reference to the other end, or it would make about $1\frac{1}{4}$ revolutions before the spring would be wound up.

The difficulty here is, in addition to the weight of the spring, its unwieldy size, which would prohibit its attachment to a street car.

3. The third form of this problem is to take such a size and form of spring as may be attached to a car, and so proportion it that it will be just wound up when the wheels slip under their heaviest load.

Let us assume that a 500-pound spring is as large as is desirable. Let this be coiled about one axle, in a coil 15 inches in diameter and 40 inches long. This would give a spring 1 inch thick. The width of the cross-section would be found from eq. (3) to be $6\frac{3}{8}$ inches for a maximum circumferential pull of 8,500 pounds on the end, which has been found sufficient to cause the wheels to slip under their greatest load.

The energy that would be absorbed by this spring, when brought to its maximum stress of 60,000 pounds per square inch, would be, from eq. (13) 3,000 foot-pounds, or only about 15 per cent. of the total energy of the moving car. The other 85 per cent. would go to waste, as it does now. Certainly it would not be worth while to attach an apparatus that could store only so small an amount.

The three special solutions of the general problem have, therefore, all led to failure when the energy was to be stored in a steel spring.

Evidently the solution of the problem, if it comes at all, must come through the use of a light and highly elastic material. We have such a

material in air. Its weight is insignificant, and it may be indefinitely compressed.

Energy stored by compressed air.—If air be compressed at constant temperature, the energy absorbed is :

$$G_t = \int_{v_0}^{v_1} p\, d\, v$$

where

G_t is energy for constant temperature;
p is the intensity of the pressure;
v_0 and v_1 the volumes at beginning and at end of the compression respectively.

But when the temperature is constant we have $p\, v = C$ or

$$p = \frac{C}{v};$$

$$\therefore G_t = C \int_{v_0}^{v_1} \frac{dv}{v} = C\, log_e \frac{v_1}{v_0} = 2.3\, C\, log. \frac{v_1}{v_0}, \qquad (16)$$

where the log. is taken in the common system.

If we take $p = 15$ pounds per square inch $= 2{,}160$ pounds per square foot, and if we take $v = 2.5$ cubic feet, then

$$p\, v = C = 5{,}400.$$

If we now assume our 2.5 cubic feet of air to be compressed to 0.25 cubic feet, then $\frac{v_1}{v_0} = \frac{1}{10}$ and log. $0.1 = -1$.

Therefore eq. (16) becomes $G_t = 2.3 \times 5{,}400 \times - 1 = - 12{,}420$ foot-pounds. The final pressure would here be 150 pounds per square inch.

The minus sign indicates that the work is done on the gas.

If we now assume that the compression occurs without loss of heat, or along an adiabatic curve (condition of constant entropy) instead of along an isometric curve (condition of constant temperature), we have :

$$G_e = \frac{p_0\, V_0}{K - 1} \left[1 - \left(\frac{V_0}{V_1} \right)^{K - - 1} \right] \qquad (17)$$

where K is the ratio of the specific heat of air at constant pressure to the specific heat at constant volume $= 1.41$.

For the conditions assumed, eq. (17) assumes the form—

$$G_e = \frac{5400}{.41} \left[1 - (10)^{0.41} \right] = 20{,}700 \text{ foot-pounds.}$$

The final pressure would be 385 pounds per square inch. The real work done, or energy absorbed, will be somewhere between 12,400 and 20,700 foot-pounds, depending on the amount of heat allowed to escape. Suppose we say it will be 18,000 foot-pounds. If no heat escaped the resulting temperature would be 804° when the initial temperature was freezing. The *amount* of heat generated would, however, be small, so that if it all passed into the cylinder at the compressed end it would raise the temperature of this ¼ inch shell only about 13 degrees F. This heat would mostly be absorbed by the shell while the car was standing, so that when it came to be started the available energy would be only the 12,000 foot-pounds for constant temperature. The loss from this cause would therefore be about one-third the energy of the moving car. The other

two-thirds, or 12,000 foot-pounds, could be utilized. If a larger cylinder were used and the air not so highly condensed, the loss would be less; but the additional size and weight of the appliance would offset the advantage, perhaps. The cylinder here discussed is 5 feet long and 10 inches in diameter, of ¼ inch wrought-iron, and with its fixtures need not weigh more than 250 to 300 pounds. The movement of the piston would be 54 inches for the maximum load, and this could be geared in such a way as to stop the car in any desired distance.

This is, I conceive, the only possible solution of the problem. The question now arises, Is it worth the trouble? The *vis viva* or energy of our moving car, with a load of 65 passengers, which could be stored on *level* ground, is perhaps not more than 12,000 foot-pounds, only two-thirds of which, or 8,000 foot pounds, would be available for starting.

But this is the saving on the maximum loaded car. If the average load be 25 passengers, then the energy that might be stored on level ground would be but about 7,200 foot-pounds, with but 5,400 foot-pounds available for starting. This would be equivalent to one horse-power exerted for ten seconds, or to the power of two horses for five seconds. If we assume 20 stops for the average car on the round trip, and each horse makes two round trips of 1½ hours each per day, then the total saving for each horse is 3⅓ minutes' labor each day, or about two per cent. of his total expenditure. When we remember that this starting is done at a low speed, when the exhaustion is not so great as the same amount of work is at higher speeds, we may well question the utility of any car-starting device, even though there were no natural impediments in the way of its application.

It must be seen that the work of starting a car is much greater than the saving above indicated, and that the three minutes' power per day for each horse is, perhaps, less than half the power now expended in starting the cars.

The cost of the animal power in horse cars is but about 30 per cent. of the total running expense, so that a saving of two per cent. in animal power would be a saving of but six-tenths of one per cent. in running expenses. Still, this might be sufficient to warrant the outlay if there were no disadvantages and nothing to offset this saving. There is such an offset in the weight of the appliance itself. Suppose this to be 300 pounds; this is about *four per cent.* of the average load. The increased tax on the team is therefore *four per cent*, and the saving not more than two per cent., leaving a net *addition* to the animal power of *two per cent.*

CONCLUSIONS.

1. That it is quite impracticable to store the energy of a loaded street car, moving at the rate of six miles per hour, in a steel spring.

2. That a considerable portion of this energy may be stored in a small cylinder of compressed air and made available for starting the car.

3. That the increased expenditure of animal power necessary to transport the apparatus would be more than the saving that could possibly be effected by storing the energy of the moving car.

NOTE.—Since the above was written an article has been published by Mr. Wilfred Lewis, in the Proceedings of the Engineers' Club of Philadelphia, Vol. IV., No. 4, on "The Resilience of Steel." He describes some experiments made for the purpose of

testing the possibility of storing energy in steel springs for the *propulsion* of street cars. The invention is described in the New York *Scientific Times*, of Dec. 15, 1883, as a "wonderful system, by which horses on street car lines will be abolished." The working parts were to be of phosphor-bronze, and there were to be 80 steel springs, each 3 inches wide by 3-32 inch thick, and 60 feet long, which were to be wound up in two minutes by a stationary engine at the depot, and the car started on its circuit. A saving clause was introduced in the shape of a ' powerful hand-winding arrangement which the engineer may apply while the car is in motion, and thus reach the station without delay!" And this scheme was practically carried to completion so far as the mechanism went, in this the scientific centre of our great scientific age! The King of the Hottentots would have hitched his engineer to the car at once and told him to pull it, and he would have been much the wiser man. Mr. Lewis was in no way responsible for the scheme, however.

BUILDING STONES OF MINNESOTA.

BY W. A. TRUESDELL, MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read April 6, 1885.]

Minnesota is quite well supplied with building stone, probably to a greater extent than any other Western State. The different formations which furnish this stone are not uniformly distributed over the country. The western half of the State is entirely destitute of rock suitable for building, but in the eastern part where the demand is greatest, and within easy access of this city, there are some ten or twelve varieties of stones, all good—some of them excellent and well adapted for the finest structures.

It is only for a comparatively recent period that we have realized the excellence of some of these stones and introduced them into work. The great activity in building during the last three or four years, and the demand for something better than that before used, has served to place in the market a class of material far superior to that which had been used during our pioneer era of building. It is now a fact generally admitted, that whatever other favorable qualities any building stone possesses, it must be frost-proof to withstand the severity of our climate. Our most available stone, and the one used for the longest period, has proved to be a failure in this respect. Time only can determine which of the other Minnesota building stones possesses this requisite to the greatest extent. A favorable architectural appearance, durability and cheapness are the most desirable features of any building stone. In these respects, Minnesota possesses several that cannot be excelled.

The northeastern part of the State is of azoic formation, and abounds in granites. This rock is found in the country adjacent to Lake Superior, along the upper Mississippi River, in Stearns and Benton counties, on the St. Croix River and generally throughout the whole northern part of the state, where it exists in several different varieties and in inexhaustible quantities. In most localities, it is too remote from lines of transportation to be of any value. The granite from the quarries at or near the upper Mississippi is the only kind now used for building purposes.

Minnesota is richest in limestones. There are several fine varieties of these which are found in the eastern and southeastern parts of the State,

along the Mississippi River, from Minneapolis to Winona and below, in the interior of the southeastern part of the State, in Fillmore, Dodge and Steele counties, and along the lower Minnesota River, from Mankato to Fort Snelling. Most of these are magnesian limestones or dolomites, containing about 40 per cent. of magnesia and fifty per cent. of lime, and all of them belong to the different groups of the Silurian system. No limestones are found anywhere north of Minneapolis or west of Mankato.

Three or four different varieties of sandstone are found in the State, or near at hand. All of them are good but they are not found in very great quantities. Only one of them, the Lake Superior sandstone, has been used to any great extent. All of these sandstones belong to the lowest geological strata.

The whole western part of the State is a prairie region, entirely covered with drift, and contains very few, if any, outcroppings of rock of any kind. The few varieties that are found in the southwestern portion are of a very hard structure, extremely difficult to work, and possess no value as building stone.

In the following discussion, each stone is designated from the locality where it is found. For all knowledge relating to the geological position, the chemical composition, and, to a great extent, the crushing strength of these stones, I am indebted to the Geological Reports of Professor Winchell, where the subject is most ably treated. General Gillmore's Report on the Building Stones of the United States has also been consulted. The weights and specific gravities are my own figures.

Most of these stones are used more or less by builders in this city. The Kasota and Frontenac stones have been in use here for a number of years. Others have been introduced later, as the quarries throughout the State have been developed, and transportation lines opened. Their cost, delivered here in the city, is governed by freights and the quantities required. They are sold by the cubic yard, cubic foot, and by the lineal foot, according to the class of masonry for which they are required. Selected stone is sold at a much higher price.

SAUK RAPIDS GRANITE.

In a list of the building stones of Minnesota the granites would naturally be placed first,—the first of all rocks in geological age and formation. Probably one-half of the whole State is underlaid with granite rocks which are exposed above the drift in numerous localities, mostly in the northeastern part of the State. These granites vary considerably in color, composition and lithological appearance, and embrace the dark-colored granite of Lake Superior, the gray Syenite of the upper Mississippi River, the trap rock of the St. Croix River, and the coarse red stone of the upper Minnesota River valley. They are all called granites, as they are of igneous formation and crystalline structure. Most of them are not adapted to building on account of extreme hardness, irregular cleavage and difficulty in quarrying and working.

The granite from the upper Mississippi, commonly called Sauk Rapids granite, is the only rock of this class that has been used to any extent in this city, and with which we are acquainted. Most of this, if not all, is obtained from the quarries of Messrs. Breen & Young, at East St. Cloud.

It is also found at other localities throughout that part of the State. Saulpaugh Bros. own quarries of the same rock at Watab, Benton County The piers of the Bismarck bridge were built of stone from the latter place.

This rock is a gray granite, or more properly a Syenite, made up of quartz and feldspar, without the elementary mineral mica which enters into the composition of granite proper. From one half to three-fourths is quartz. The remainder is mostly feldspar. There is very little hornblende. Sauk Rapids granite is a very hard rock, rather difficult to dress and quarry, but when once placed in work will last forever. Its characteristics render it a very valuable building material, where anything of a substantial nature is required. It is a stone of great strength. As tested by General Gillmore, it was found to sustain a pressure of 16,000 lbs. to the square inch. Professor Winchell gives the crushing weight from 21,500 lbs. to 28,000 lbs. It is evident, from these figures, that Minnesota granite compares favorably with the granites of the New England States. The strength of Quincy granite is from 14,750 lbs. to 17,750 lbs. Sauk Rapids granite ranks above most of the one hundred specimens of rock of this class gathered from all parts of the Eastern States, and tested by General Gillmore. It is impregnable to the disintegrating effects of frost, alternate dryness and moisture, and atmospheric action. The ratio of absorption is 1-239. Carbonic acid does not affect it. It is susceptible of a fine polish, which gives it value for works where architectural effect is wanted, such as columns for fronts and for cemetery works. For the facings of bridge piers to the water line, and in ice breakers and pier copings, it is unsurpassed. In trimmings to buildings of a substantial character, in water tables, sills and columns, no better stone can be obtained. The city authorities here are now using it for curbstones on all streets which are paved, as it is about the only stone that will endure the wear and tear of street traffic, and the intense cold of our winters.

This stone can be obtained from the quarries in almost any size and shape. It is first broken by blasting, and then brought near the required shape by plug and feather. The smaller pieces are worked into paving blocks. Its cost, as given by Messrs. Breen & Young, is as follows for stone delivered in St. Paul: Bridge stone in the rough, $12 per cubic yard; trimmings, cut and dressed, $1.50 per linear foot; curbstones, $1.05 per linear foot; paving blocks, $75 per 1,000.

The gray variety of the Sauk Rapids granite is altogether the best stone we have for important work. Its extreme hardness and difficulty of dressing make it the most expensive, though its cost is not so great as to exclude it from structures of a substantial character. The composition and physical qualities of this stone are all so favorable that it must always rank first as to durability. All granites are, however, less durable under exposure to fire—as experience proves—than other stones of, in other respects, an inferior character. The red granite contains less quartz and more feldspar. It is not so hard or difficult to dress as the gray variety, but is inferior to it in quality, and it is more susceptible to decomposition from the action of frost and moisture.

DULUTH GRANITE.

The Duluth granite, or as it is usually called "gabbro," is a dark-col-

ored rock, extremely hard in texture, and abounds at Duluth and the surrounding country. It is made up mostly of feldspar and horn-blende, and usually contains a large percentage of the oxide of iron. Unlike the other granites, it contains no quartz in its composition, and, strictly speaking, it is not a granite. The quantity of iron is sometimes so large in this rock that it may be considered an iron ore of low degree. It is a very hard and expensive stone to quarry and dress, which destroys its value as a building material. Its use, so far, has only been local. At Duluth it has been used in foundation walls and trimmings. Its principal use at present is for monuments and other cemetery works. As it will take a high polish, it is well adapted for that purpose. It is the heaviest of all Minnesota stones. Its weight is 175 lbs. per cubic foot.

SIOUX FALLS GRANITE.

The rock known as Sioux Falls granite, or "jasper," is found in the southwestern part of the State, in Cottonwood, Pipestone and Rock counties, and on the Big Sioux river in Dakota. It is also found in large quantities on the Minnesota River at New Ulm. It is a red quartzite or metamorphic sandstone, and consists mostly of quartz—about 85 per cent. Its reddish color is due to a small amount of the oxide of iron. The crushing weight of this stone is 28,000 lbs. It is undoubtedly the hardest rock known in this country. Though it is the only stone of any kind found in the whole southwestern part of the state, it does not appear to have been used to any great extent. Its extreme hardness and the expense of dressing and quarrying it, render it unfit for general masonry. It has been used some in foundation walls. The Queen Bee flouring mill at Sioux Falls is built of it Very little of it has been shipped to this city. The best use to which it can be applied is in street paving; and if the hardest material is considered the best for paving, this rock must take precedence above all others for that purpose. It is also well adapted for ornamental trimmings, monuments, furniture, etc., for it has a fine appearance when polished.

There are large quantities of granite found along the Minnesota River from Redwood Falls to Bigstone Lake. At Granite Falls, Montevideo and other localities it exists in immense quantities. The bottom lands of the river at these points are entirely covered with it. This is a stone softer than the Sauk Rapids granite, having less quartz. It is a coarse-grained red granite, breaks and cleaves into irregular blocks and is difficult to quarry into any shape suitable for building. It appears to be little used in that part of the country and has no market value.

LAKE SUPERIOR SANDSTONE.

Next in an ascending order above the granites come the sandstones. Rocks of this class are found in Minnesota at Lake Superior, on the Grindstone River, at localities on the Mississippi River, at Jordan on the Minnesota River and as a quartzite at New Ulm and other places in the southwestern part of the State. All of these rocks belong to the Potsdam formation, the first stratified rock known in geology. As they differ apparently in their characteristics, they are commonly known as different stones and under their local names. Most of them are good building material, and are destined to an extensive use as our State grows older.

The Fond du Lac, or Lake Superior, brownstone is found in great abundance along the entire southern shore of that lake. It has been used at Duluth to some extent, and has been shipped to Milwaukee and Chicago, and extensively used there in buildings. At first it was sparingly used in this city, but of late years it has become popular, and at present a few of the finest buildings here and at Minneapolis are constructed of that material.

This sandstone is of a dull red or brown color, and is composed mostly of quartz, about 80 per cent. It contains about 4 per cent. of iron. Its weight is 141 lbs. per cubic foot. The crushing strength is 8,800 lbs. to the square inch. It can be quarried in almost any size and thickness, but is usually taken out in irregular pieces, though sometimes the beds are even. It does not dress unusually hard. In the yards on the upper levee it is worked and sawed into trimmings and dimension blocks. Its cost at the quarry is about $3 per cubic yard. Stone suitable for buildings would cost 50 cents per cubic foot, in the rough, delivered here.

The Lake Superior brownstone is not, perhaps, equal to some of the Eastern sandstones for fine work, but in this Western country, where sandstones are not found in abundance and great variety, it is a valuable building material. It has seldom been used in bridge work, as stone better adapted for heavy masonry can be readily obtained. Its use hereafter will probably be confined to buildings, either as trimmings or for the entire work. For this purpose the Lake Superior brownstone, together with the Kasota stone, will undoubtedly be the building stones of the future. When this sandstone is placed in work, and built rock-faced and in the broken ashlar style of masonry, it presents a fine appearance. Unlike stone of a lighter color, it will not discolor with age. This is one of its best features. Frost and atmospheric changes do not affect it. The building on the corner of West Third and St. Peter streets contains water tables and window caps put there over ten years ago. Their present appearance shows no indications of climatic influences. The favorable qualities of this stone are now acknowledged by builders, and it is often found in buildings throughout the city. The first story of the German-American Bank, the Gamble and Griggs residences on Summit avenue, and the Westminster Presbyterian Church and the McNair residence in Minneapolis, are the principal buildings where this stone has been used. In architectural appearance they will compare favorably with any other buildings in the two cities.

HINCKLEY SANDSTONE.

The Hinckley sandstone is found in abundance on the Grindstone, Kettle and Pine rivers, on or near the line of the St. Paul and Duluth Railroad. It crops out in numerous places on those streams and a few lakes in that vicinity, and appears to underlie most of the country traversed by those streams. It belongs to the same formation as the Lake Superior stone. This sandstone is of a red or pink color, and is composed entirely of quartz. Its strength is remarkable for a sandstone, 19,000 lbs. to the square inch. This is more than twice that of the Lake Superior stone, and not much inferior to that of granite.

The only use so far made of this stone has been by the St. Paul and Duluth Railroad Co. The abutments of the bridges at the above men-

tioned streams are built of it, and it has been used to some extent in foundations for engine houses, turn-tables, etc.

The quarry at Hinckley has not been opened sufficiently to determine the true value of this stone. The section already exposed is from six to nine feet in height, and about two hundred and fifty feet long. The ledges vary from a few inches to two feet in thickness. They are not very regular, but will probably improve as the quarry is developed. The stone itself is of good quality. It is not unusually hard or difficult to dress. It appears to be well adapted for bridge and general masonry. If it can be obtained in large dimensions and sufficient quantities, it will in time, undoubtedly, be considered a valuable stone, and extensively used.

DRESBACH SANDSTONE.

Another variety of sandstone is found on the Mississippi River at Dresbach, about twenty miles below Winona. Messrs. Tosteven & Co., of St. Paul, who own a quarry there of nine acres, are now bringing the stone to this city; but its use, so far, has been limited. The only building here constructed entirely of it is the Episcopal Church on Mackubin street, between Laurel and Ashland avenues.

It is a fine-grained stone of gray color, and light in weight, 122 lbs. to the cubic foot. About 80 per cent. is quartz. When first quarried it is wet and soft and easily worked, but in time, as it becomes seasoned, it grows much harder and acquires greater strength. The crushing weight is 6,500 lbs.

There are two varieties of this stone obtained from the same quarry. The ledge that is worked is about eight feet in depth. The presence of water prevents quarrying to a greater depth without great expense, but borings made eighteen feet below the level of the water show that the rock reaches to that depth, at least. The upper part of this eight-feet ledge is of a gray color and is called the buff rock. The lower part, near the water, is of a darker color and is called the blue rock. This appears to be much harder than the upper ledge. Large dimension stones can be obtained from this quarry. The thickest ledge is twenty-eight inches and the beds are regular and even.

If this stone should prove to harden well after being thoroughly seasoned, it will undoubtedly, from its fine grain and handsome color, become a popular building material in this city, and may supplant the Ohio sandstone, which it closely resembles. The cost of Dresbach stone in this city is 45 cents per cubic foot, in blocks of large dimensions—about one half the cost of Ohio and Indiana sandstones.

The Lake Superior, Hinckley and Dresbach stones are all the sandstones that are known at present to exist in Minnesota which can be called building stones. Other quarries may be opened and developed ultimately. There is a sandrock at Jordan and another at Taylor's Falls, but little is known of them, and their use, if used at all, is only local.

Within a very short time there have been shipped to this city a few car loads of a new variety of stone from Dunnville, in Wisconsin, on the line of the Chicago, St. Paul and Omaha road. Though this is not a Minnesota stone it may be well to mention it here. Ulmar & Smith, on the upper levee, are the owners or agents of this quarry, and they are now

sawing the stone into trimmings for use in this city. This is a fine variety of sandstone, of gray color and resembles the Dresbach stone, and is perhaps superior to it in quality. The ledge from which it is obtained is six feet thick. Stone can be quarried in blocks of large size. Like the Dresbach stone it is soft and wet when first taken out, but hardens by time and exposure. It is easily worked into ornamental trimmings, for which use it seems to be well adapted. No tests have been made of its strength, but it appears to be as hard as ordinary sandstone.

ST. PAUL LIMESTONE.

The St. Paul limestone is the building material which has heretofore been mostly used in this city, but time has proven to us its defects ; and in all probability it will soon be supplanted by imported stone of a better quality for all structures which are intended to be substantial This stone is found in large quantities at St. Paul and Minneapolis, cropping out on the river bluffs, and overlying the sandrock. A large portion of this city is built immediately over an extensive stratum from which most of our building stone has been taken. This is the Trenton limestone, the fourth stratified rock in order of formation that is found in Minnesota. The immense quantities of this stone here and at Minneapolis constitute the most northern limits of this formation found in the State. The same stone is again met with, further south, at Northfield and Faribault, from whence it diverges southeast and southwest, and extends down into Iowa.

In composition, 75 or 80 per cent. is lime ; about 6 per cent is magnesia—not enough to make it a magnesian limestone. In weight, it is quite heavy—165 lbs. to the cubic foot—equal in this respect to some of the granites.

The stone taken from the quarries in the south part of the State has less of that friable, shaly texture, and is said to be of much better quality than the stone obtained in this city. Here the stone has less lime, and a little sand in its composition. Further to the south, it is a purer limestone and appears to be a stone of greater strength. For instance, the strength of St. Paul limestone, as given by Professor Winchell, is 19.400 lbs. to the square inch ; the Minneapolis stone at 17,400 lbs., while stone from the same formation in Fillmore County sustains a pressure of 26,000 lbs., a strength equal to Sauk Rapids granite.

Several quarries are at present worked in this city. They are substantially the same as to the depth of the rock and the quality of stone. A section of one of them would present about this appearance :

First, the soil or drift, in some cases ten or twelve feet in depth. Second, a layer of shell rock from two to three feet deep—useless for any purpose, except, perhaps, macadamizing. Third, a layer of shale, two or three feet thick, usually called soapstone. This is a worthless material, though contractors will work it into a wall if there is no inspector in sight. Fourth, the rock proper—a stratum from ten to twelve feet in depth, and sometimes fourteen feet. The West St. Paul quarries vary somewhat from this description in one instance. Immediately under the shell rock and over the soapstone is a layer from eight to nine feet in thickness, called by the quarrymen "graystone." This is sometimes

erroneously confounded with the worthless shale or soapstone. It is an impure limestone, of dirty gray color—very little grained; is harder and a better building stone than the regular blue stone. Wherever it has been placed in buildings years ago, its greater durability can be noticed. An examination of the piers of the Wabash street bridge is proof of this. There is one drawback pertaining to it, which will apply, perhaps, to many other kinds of stone—it cannot be quarried in the winter. As it contains a large amount of moisture when first quarried, extremely cold weather will crack and break it: but when taken out in warm weather and thoroughly seasoned, it is fully as good as, if not superior to, the blue stone.

The ledge of rock found in all St. Paul quarries from ten to twelve feet thick, is the one which furnishes all our building stones. From this ledge the rock can be quarried in blocks of different depths, varying in the different quarries, but ranging from six inches in thickness to perhaps twenty-four inches. These stones come out in very even beds and sometimes in lengths of ten or twelve feet. Yet dimension stone of large size is difficult to get without great waste.

The great defect of the St. Paul stone is its inability to withstand our severe climate. So far as strength alone is concerned, it is suitable for any purpose; but under the changes of moisture and dryness—thawing and freezing—it will crumble in time, as will be noticed in some of our oldest buildings. This has finally become apparent to most of our builders, and more durable stone is now imported and used. Another disadvantage to the St. Paul stone is the great cost and labor in getting it out. In all the quarries, except perhaps those on West Seventh street, and especially in those in West St. Paul, there is from ten to fifteen feet, and often more, of earth to remove; then five to six feet of shell and shale rock; afterward eight to nine feet of graystone before the bluestone is reached, all of which requires an expenditure of about three dollars to get out one dollar's worth of rock.

While the stone quarried in this city cannot be considered a durable building stone, there are a great many instances where it will answer the purpose intended and can be used to advantage. For foundation, side and rear walls of buildings—for rubble masonry, backing and filling—and in all cases of inferior and unimportant work, it is well enough to use the St. Paul stone; but in the larger and more substantial buildings—in bridge piers, and in all work that is intended to endure, the use of this stone should be discouraged.

The St. Paul limestone is now considered a very inferior article for building, and its use in first-class work will undoubtedly soon be discontinued altogether. Its greatest defects are its capacity to absorb moisture—the avidity with which carbonic acid will act upon it—to a greater extent than on any other Minnesota stone—and the clayey seams which usually constitute a large part of its structure. The destructibility of this stone is owing to all of these features, more especially to the last one. Clay is a detriment in any building stone, as it absorbs moisture and renders the stone softer and presents a greater opportunity for the action of frost. The clay seams will, after long exposure, disintegrate and crumble, leaving the alternate seams of limestone in their original

condition. This is the great fault with the stone quarried in this city, and is the cause for that decaying appearance to be seen in all of the older work built of that material. However, there is one stratum of this stone to be found in all of the St. Paul quarries, nine inches in thickness, which builders claim is as durable as any of the imported stone and which frost does not affect. Work built of St. Paul stone should always be rock-faced, as it makes a better appearance and protects the stone somewhat against atmospheric action. Ashlar masonry of this stone should be avoided. All work of this kind presents an unsightly appearance within a few years after completion.

Stone adapted for heavy masonry is sold at the quarries in this city for $4 or $5 per cubic yard. Trimmings, from 15 to 18 cents per foot. Rubble stone at about 75 cents per perch, and range rock at 10 to 12 cents per foot. Good masonry can be built of this stone at $8 or $10 per yard, which is $5 or $6 cheaper than Red Wing or Kasota masonry.

RED WING STONE.

There is a magnesian limestone existing in unlimited quantities along the Mississippi River, which forms the upper part of the bluffs lining that stream, and is seen exposed at a great many localities as far south as the southern boundary of the State. This rock is quarried at Stillwater, Langdon, Nininger, Red Wing, Frontenac, Winona and Dresbach, and also at places along the banks of the streams which flow into the Mississippi from the west. These are commonly supposed to be different varieties of stone, all differing from each other, and are known among builders according to the above localities where they are obtained. Though differing somewhat in appearance and physical qualities, they are in fact one kind of stone, essentially the same in their chemical ingredients, and belonging to the same geological formation—the Lower Magnesian, the oldest limestones known in geological history. They are all magnesian stones, or more properly dolomites, and generally contain about fifty per cent. of lime and forty per cent. of magnesia. When this stone can be obtained of a close texture and free from porosity, it is a most excellent building material. Magnesian limestones are generally considered much better and more durable than the limestones proper.

This formation of stone, extending from Stillwater to Winona and below, is probably the most extensive and valuable quantity of building stone anywhere in the Western country. It has furnished stone to a large extent ever since that material has been used in the State, and is, without doubt, the great source from which the greater part of our building stone will be obtained in the future.

The Stillwater stone has been quarried for a number of years, and used in buildings in that city. Very little, if any, has been sent to St. Paul. It is very heavy in weight—173 lbs. to the cubic foot—the heaviest of Minnesota limestones, and of about the same weight as Duluth granite. Its crushing strength varies from 10,000 to 25,000 lbs. per square inch.

The stone at Langdon, owned and quarried by Messrs. Breen & Young, of this city, bears a very close resemblance to the Red Wing stone, and is probably equal to it in every respect. This is an excellent material for bridge work and heavy masonry. It has been used some in this city for

foundation walls. Its proximity to St. Paul ought to make it the cheapest stone that can be obtained here.

The Frontenac stone is well known here and at Minneapolis, where it has been used for several years, mainly as trimmings. It can be seen throughout this city in quite a large number of buildings. The front walls of the Commercial Hotel, on Seventh street, and the trimmings of the State Capitol are of Frontenac stone. It can be easily sawed and worked into ornamental shapes, and when bush-hammered, is suitable for sills, caps, pilasters, etc. Its greatest defect is its porosity and capacity to absorb moisture. The ratio of absorption is 1-21. As it is of a light color, it will in time become stained and discolored from exposure. In weight and strength it is about the same as the Lake Superior sandstone. General Gillmore, in his Report on the Building Stones of the United States, erroneously classes this stone as a sandstone.

The stone quarried at Nininger, by Lauer Bros. of this city, belongs to the same class of magnesian limestones under discussion, and possesses the same favorable features as the others, but is the lightest in weight. It can be obtained in blocks of large size, and is worked and sawed with great facility and presents a good appearance in work. The stone has been introduced here recently, but is used already in a large number of buildings. Like the Frontenac stone, it is better adapted for architectural fronts and trimmings than for heavy masonry.

The stone which has been quarried at Red Wing for a number of years, and extensively used, is now acknowledged to be superior to any other stone in the West for bridge work and heavy masonry. No better material could be required for that class of construction. It is not equal, perhaps, to the Kasota stone for buildings, as it does not take so fine a finish and costs in dressing about 25 per cent. more. It has been used to a considerable extent in buildings, and when bush-hammered answers very well for that purpose. But its superiority is for bridge work, on account of the great-sized pieces in which it can be obtained, its durability and its great strength—23,000 lbs. per square inch.

KASOTA LIMESTONE.

The favorite building-stone heretofore used in this State is the Kasota limestone. formerly called, by mistake, a sandstone. It is entitled to all the praise it has ever received, for there is no better material for all classes of work where stone is required anywhere in the West, or even in the United States. There is no necessity of bringing Joliet stone, Berea sandstone, or any other stone to this city while we have a material superior to them all so close at hand.

This stone attracted attention at an early day, and was the first imported stone ever used in this city. It is adapted to every kind of stone work, and its use, especially in buildings, has been most extensive. To enumerate at present all the buildings here and at Minneapolis where it has been used, would be quite a task. Its attractive color and appearance, whether in the ashlar or rock-faced style of masonry, renders it a desirable material for the finest and most ornamental buildings. The First Baptist Church, altogether the finest church edifice in this city, was built entirely of this stone in 1874. The two largest and most elegant residences in the West—the Kittson, on Summit avenue, and the Wash-

burn, in Minneapolis, are also constructed of this stone. The former is ashlar work and the latter rock-faced. It is questionable which presents the best appearance.

The Kasota stone is also a magnesian limestone, made up of about the same proportions of lime and magnesia as the Red Wing stone, and belongs to the latest strata of the same formation—the Lower Magnesian. It is found in the lower part of the Minnesota Valley in unlimited quantities, and appears to form a substratum to the whole country from Mankato to Shakopee. It has been quarried for a great many years at St. Peter, Kasota and Mankato, along a portion of the valley about fifteen miles in length. All the quarries at these three localities have been worked extensively and have furnished stone for years, to all parts of Minnesota, Dakota and Nebraska. The stone can always be taken out in even and regular strata, from a few inches in thickness to twenty-four inches, and in blocks of the largest size. Pieces ten, twelve and even fourteen feet in length are not uncommon. Most of these quarries can furnish stone for any variety of work. Flagstones, trimmings, and all kinds of cut and dimension stones are abundant, and the largest bridge stones have been used in the construction of the several bridges over the Minnesota River, the St. Paul, Minneapolis & Manitoba Railway viaduct, and the masonry of the Seventh Street Improvement.

Kasota stone weighs from 151 to 157 lbs. per cubic foot, and has a strength ranging from 13,000 to 18,000 lbs. It can be worked and dressed or sawed with great facility. Experience proves it to be a stone of great durability for this climate. In all structures where it has stood for a number of years it appears to withstand the action of frost and atmospheric influences. There are at Mankato buildings constructed of this stone over twenty-five years ago. They present to-day as good an appearance as when first built, and are not stained or discolored to any extent, which is an important quality in any building stone.

The largest quarry from which this stone is obtained is the one at Mankato, known as the Empire Stone Ledge, owned and worked by W. B. Craig & Co. Stone is taken out and handled here with great facility, and at the least cost possible.

The ledge is about thirty-five feet in height, and is opened and worked along a frontage of 1,500 feet. Two railroad tracks extend through the quarry its entire length. Stone can be procured here for any purpose and adapted to all varieties of work, from the thinnest flagstones to the heaviest bridge stones. There are ten or twelve distinct and different strata in even and horizontal beds—four of which will furnish dimension stone of the largest size, from a few inches in thickness to thirty inches. The upper portion of the quarry for ten or twelve feet is composed of stone in thin and broken layers, suitable only for riprap, rubble, etc.; then the first ledge of importance is reached, called the Red Ledge. This is four feet thick, of a red or pink color, and is similar in texture and appearance to that found at Kasota. Stone from this ledge is adapted for bridge masonry, trimmings, cut and dimension work of all kinds. This ledge and the lowest one are superior to anything else in the quarry. Four feet lower is the soft ledge, which furnishes a stone mottled in color and very easily worked. This is used altogether for trimmings,

but as it will take a fine polish, it can be wrought into table tops, mantels, furniture, etc.

Next comes the Bridge Ledge, six feet thick, and of a straw color. This is a coarse, hard and strong stone, but easily worked, obtained in the largest sizes and excellent for heavy masonry, but not suitable for finer work. This is wet and saturated with sap when first quarried, but soon seasons by exposure.

Two feet below the Bridge Ledge, and separated from it by a layer of shale two feet thick, is the Cutstone Ledge, the bottom of the quarry. This is four feet thick, of a buff or light gray color. The stone is close and compact, with a fine texture, and is easily dressed. For ashlar work, it is the finest stone in Minnesota. For trimmings to any building, this stone is superior to those imported from the Eastern States at double the cost.

The facilities for getting out and handling stone at this quarry are first class. In the summer of 1884 there was furnished for the Seventh Street Improvement arches in this city 1,764 stones averaging 24 inches by 24 inches by 6 feet in dimensions. All of these were quarried and cut from the Red, Bridge and Cutstone ledges in three months' time. The capacity of this quarry will be better understood when it is remembered that only about twenty-five per cent. of all the stone taken out was suitable for the above number of archstones required.

The quarries at Kasota, seven miles distant, are on the level prairies and are not worked with so great facility as those at Mankato. Water is often a troublesome element, which prevents a quarry from being developed to its full depth and capacity. The stone obtained here is similar to that from the Red Ledge of the Empire Stone quarry.

It is apparent from the above list of stones that our State is abundantly supplied with building material of great superiority. The quarries of Sauk Rapids, Lake Superior, Red Wing and Kasota can furnish granites, sandstones and limestones of qualities and in quantities sufficient to meet the widest range of building requirements. It is only during the last few years that the favorable qualities of these stones have been known. We are just entering upon our era of stone building, and the future will show a great demand for the many excellent building stones which constitute one of the most important resources of our State. The present is called the age of iron. Without reversing the order of history, it can truly be said that the stone age in Minnesota is about to commence.

The following tabular statement is a recapitulation of some of the facts stated above, and will be useful for reference as showing the most important qualities of Minnesota building stones. Most of it was derived from advance sheets of Volume I., of Professor Winchell's Final Report on the Geology of Minnesota. The ratio of absorption represents the capacity of a stone to absorb moisture. The fraction under this head and opposite each stone indicates the weight of that stone, when dry, which will absorb one pound of water after immersion for a considerable length of time. For instance, a piece of Dresbach sandstone weighing eight pounds will absorb one pound of water. This is the most defective stone in this respect on the list. The strength per square inch of each stone was ob-

tained by experimenting on a piece two inches cube, and dividing the number of pounds ascertained by four. This gives results much greater than the crushing weights formerly attached to the different varieties of stones.

MINNESOTA BUILDING STONES.

Name of stone.	Weight per cubic foot.	Ratio of absorption.	Strength in lbs. per square inch.
Granites:			
Duluth	175	$\frac{1}{335}$	27,250
Sauk Rapids	166	$\frac{1}{239}$	21,500 to 28,000
Sioux Falls (quartzite)	162	$\frac{1}{366}$	27,000
Sandstones:			
Lake Superior	141½	$\frac{1}{16}$	8,750
Hinckley	139½	$\frac{1}{17}$	19,000
Dresbach	122	$\frac{1}{8}$	6,500
Limestones:			
St. Paul	165	$\frac{1}{59}$	19,500
" graystone	156	$\frac{1}{24}$	
Red Wing	156½	$\frac{1}{40}$	23,000
Laugdon	157½		
Frontenac	142½	$\frac{1}{21}$	6,250 to 11,250
Stillwater	160½	$\frac{1}{40}$	10,750 to 25,000
Nininger	137		14,000
Kasota	157½	$\frac{1}{28}$	10,700 to 18,500
Mankato (Red Ledge)	151		
" (Bridge Ledge)	153½		Same as Kasota stone.
" (Cutstone Ledge)	157		

WHAT IS THE BEST MATERIAL FOR STREET RAILROAD RAILS?

By Augustine W. Wright, Member of the Western Society of Engineers.

[Read May 5, 1885.]

I was asked at a convention of the American Street Railroad Association: "You would recommend the use of steel rails for street railroads, wouldn't you?" I replied in the affirmative, and felt safe in stating that one steel rail would outwear *six* iron rails. I spoke from my experience upon steam railroads; but this question turned my thoughts to that subject, and to-day I would hesitate to recommend steel for street railroads. The requirements of a rail upon a street railroad and upon a steam railroad are quite different, and the experience of the steam road is of little benefit to the street railroad. Upon the latter, as usually constructed, the rail is provided merely as a wearing surface. My tracks are constructed as follows: Cedar cross-ties, seven or eight feet long, as the case may be, six inches thick, with face not less than six inches, are spaced four feet between centres. Upon them stringers are laid lengthwise of the road, from twelve to thirty feet in length, five inches wide, and seven to twelve inches in depth, as may be determined. The cross-ties are securely tamped with iron bars. The stringers are likewise tamped hard between the cross-ties. The road, therefore, has a continuous timber bearing upon the earth. All that is required of the rail is to furnish a wearing surface to protect the said timber structure. Steam railroads, as ordinarily constructed, use the rails as girders, to carry the weights superimposed from bearing to bearing, *i. e.*, from cross-tie to cross-tie. They must be strong enough when the head is worn out to carry this load. Thus far the require-

ments of the two systems are entirely at variance. Now for the wearing effect of the traffic. In what does it consist? Dr. Dudley, the accomplished chemist of the Pennsylvania R. R., has advanced a theory. It has been much discussed. Allow me to quote Dr. Dudley, who, upon "The Wearing Power of Steel Rails," said: "The forces that act between the top of the head of the rail and the wheels in rolling friction may, it seems to me, be regarded as two in number. There is first a force acting directly downward, due to the weight of the locomotives and cars. This force may be regarded as a vertical force acting perpendicularly to head of the rail, and is in action both when the train is standing still and when it is in motion. Secondly, there is a force acting parallel to the head of the rail, due to the traction or impelling power of the locomotives. In the case of the driving wheels, this force may be supposed to act in the direction opposite to that of the motion of the trains. * * * In the case of the drivers, the amount of this force, acting parallel to the head of the rail, is sufficient to overcome the total train resistance; in other words, to cause the train to move. In the case of the other wheels of the train acting individually, this force acting parallel to the head of the rail is small, being only that necessary to overcome the journal friction. The force parallel to the head of the rail acts only when the train is in motion.* * *

"Returning for a moment to the conception previously mentioned, that the top of the head of the rail and the surface of the wheel are a rack and pinion with infinitesimal teeth, but without regularity in the teeth, let us see what kind of strain would be produced in these minute teeth by a force acting diagonally to the line of the head of the rail I hardly see how we can avoid the conclusion that this strain would be a bending strain. * * * If we are right in regard to the nature of the surfaces involved in wear and the strains produced, wear is simply the breaking or pulling off of the infinitesimal teeth by the strains to which they are subjected. And here we see why it is that the softer rails give the better wear; for the harder the steel, the more brittle it is; and the more brittle the steel, the more readily will these infinitesimal teeth be broken off by the strains applied."

A Pennsylvania engine for passenger service, Class K, weighed in working order 96,700 lbs., of which 32,900 lbs. was on the forward drivers. Our worthy vice-president, Mr. Chanute, made some experiments upon the Erie Railroad. He found that a driving wheel five feet in diameter bore upon the rail head a space not greater than the thickness of a knife blade—about one quarter of a square inch. Ten thousand pounds being the weight upon this driving wheel, the static pressure equaled 40,000 lbs. per square inch. THIS is the great force coming upon steam railroad rails! It is to stand up under the locomotive that the rails must be designed. It is the locomotive that does the damage and makes the greatest wear upon its rails. *Now, this force does not exist* upon a street railroad. All the rail has to do is to resist the wear coming from journal friction, and, as stated by Dr. Dudley, it is very small. The journal and flange friction at six miles per hour is probably not more than six pounds per ton. Upon your steam railroad you now, with the great and increasing weight of your locomotives need a *stronger* substance than iron, and this steel is.

I have used the words iron and steel. What do they mean? It is the same as if I spoke of wood or stone. There are many varieties of both, possessing very different qualities as to hardness, strength, etc., etc. Iron, when chemically pure, is one of the elements. Its atomic weight is 56, but it is doubtful if it occurs native. Its *ores* are very numerous, and they vary greatly in quality. In speaking of "iron," therefore, I mean the ordinary commercial article known by that name, and of average quality and workmanship. A certain addition of carbon changes the appearance and quality of the product. Thurston states: "Steel is variously defined by acknowledged authorities, and the metals known in the market and to the trade as steel cannot be completely and satisfactorily classed under any definitions yet proposed. The term includes, as formerly accepted, all impure irons which, in consequence of the presence of other elements, have the property of hardening by sudden cooling from a high temperature and of taking a definite 'temper' or degree of hardness by a definite modification of temperature, and which may also be forged. It has been recently proposed to define steel as a compound, consisting principally of iron which has been rendered homogeneous by fusion; still another definition is iron recarbonized." An iron rail is, as it were, made fibrous by the process of rolling. A steel rail is homogeneous and not fibrous. The iron rails upon steam railroads failed chiefly by lamination. Louis Nickerson wrote: "Lamination is the result of some natural and determined law, and that law is this:

"That all material, when subjected to pressure, laminates in planes perpendicular to that pressure."

This law was announced by Prof. Tyndall after his experiments upon lamination. Ure's Dict. of Min. and Mines does not agree therewith. It states: "Careful examination convinces the writer that whenever lamination of the rail becomes evident, it can be traced to the imperfect welding together of the bars of which the rail is formed." And again: "An objection has been urged against malleable iron rails on the ground that the weight on the wheels rolling on them expanded their upper surface and caused it to separate in thin laminæ. In many of our large stations rails may be frequently seen in this state, layer after layer breaking off; but this may be regarded rather as an example of defective manufacture than anything else."

Holley & Colburn wrote: "Rails rarely *wear* out. They laminate or crush in the majority of instances." This applied to *iron* rails. Ashbel Welch, chairman of a committee, reported to the Am. Soc. Civil Engrs., May, 1875, upon the subject of rails, from which I extract: "The chairman of the committee was so much surprised at so little difference in the loss of metal in iron and steel rails, that since the former report was presented he made further examinations. * * * The average loss of metal per annum was, in the steel, 0.29; in the iron, 0.325 pounds per yard. This shows if iron was perfectly welded and as hard in the middle as at the top, and never loaded so as to crush or condense the metal (say not over 25,000 pounds per square inch), it would wear nearly as long as steel."

It would appear from the above quotations that the cause of failure of iron rails upon steam railroads, supposing the rails to have been prop-

erly made, has been caused by the locomotives' excessive weight. This is absent from our horse railroad, and I am not surprised at the following results, as stated by D. K. Clarke: "Preparatory to deciding upon the material—iron or steel—for the rails (Glasgow tramway) of the new system of way designed for haulage by mechanical power, the results of the comparative wear and tear of iron rails and steel rails under like circumstances were investigated by the engineers, Messrs. Johnstone and Rankine. Two rails of the earliest sections, one of iron and one of steel, laid in Paisley road, within a few yards of each other; and two rails, one of iron and one of steel, laid in Argyle street, were weighed when they were laid and when they were taken up. The loss in weight of the Paisley road rails, 7 years, was: iron, 44 pounds; steel, 43½ pounds: Argyle, 6 years, iron, 39 pounds: steel, 33 pounds. John W. Cloud, of the Pa. R. R., in the discussion upon Dr. Dudley's paper, from which a quotation has been made, stated: "We should study the physical properties of steel in relation to its wearing power, and ask the makers to give us the requisite physical properties, and leave the chemistry to them. The evidence that softer steel does give greater wear in rails is conclusive. At Altoona, careful examinations have lately been made of locomotive tires, and from one to two inches difference have been found in the diameters of the tires of wheels upon the same axle. Invariably when these two tires are put into the lathe it is found that the tire the most worn is the hardest." Iron glides imperceptibly into steel; it is difficult to fix the boundary; and it appears that the more nearly the steel approaches iron, the better the rail upon steam roads. Upon a portion of the Great Eastern road in Great Britain, wrought-iron rails wore thirty-three years! Upon the Montreal street railway, wrought-iron rails have worn twenty-three years. Upon your steam railroad, the coning given to the wheels allows only a very small surface to come in contact with the rail head. Mr. Forney, in his paper "Rail Sections and Flange Wear," states that the load thus brought upon the rail head is from 40,000 to 60,000 pounds per square inch. The *Railroad Gazette*, Nov. 28, 1884, states "that a cast-iron car wheel of one of the patterns now largely in use, when running with its flanges against the side of a certain rail, largely used, has a cross-bearing of no more than $\frac{3}{16}$ inch in extent. The area of the bearing surface under a 33-inch wheel in such case is ⅛ square inch. With the surfaces between wheels and rails no greater than they now quite commonly are, the weight borne by the opposing surfaces is in case of a fully loaded eight-wheel twenty-ton car about 60,000 pounds per square inch."

A prominent manufacturer of car wheels tells me that he gives a slope or cone of ⅛ inch in four inches upon his steam car wheels, and $\frac{1}{16}$ inch in two inches for the street car wheel. My stringer being dressed to pattern, I give its top such an inclination that my car wheel has a *continuous* bearing across the rail head, two inches.

The weight of an average American street car is 4,700 lbs., or say 1,200 lbs. per wheel; and 6,000 lbs. is the greatest weight I have ever known upon a street car wheel from dead weight and live load. As the bearing is say $\frac{3}{16}'' \times 2'' = \frac{3}{8}$ of a square inch, and the load 6000 lbs., it equals 16,000 lbs. per square inch, or about two-thirds the weight Mr. Welch considers necessary to condense or crush an iron rail.

The speed upon your steam roads is an important factor in the wear of rails. The speed upon the horse railroad does not usually exceed six miles per hour. I have tried to find experiments upon the relative abrasion of iron and steel. Rennie's experiments indicated that dry surfaces were abraded by the following weights in pounds per square inch: Wrought-iron on wrought-iron, 560; wrought-iron on cast-iron, 709; steel on cast-iron, 672. Our car wheels are chilled cast-iron. It would appear from the foregoing experiment that the iron rail would require 5 per cent. greater pressure than the steel to have abrasion begin. Our rails are *ground out*. If of fair workmanship and quality of iron, the weight is not sufficient to cause lamination; they must then fail from wear. The mud that covers our streets nine-tenths of the time affords a grit of greater or less sharpness, and the constant grind cuts off the rail's surface. This constant grind also tells upon our car wheels. The manufacturer who furnishes our wheels makes a wheel for steam roads that he guarantees to run 60,000 miles. Increased speed and the more general use of air-brakes, etc., etc., has caused this guarantee to be now reduced to 50.000 miles. The same metal and equal care, in the manufacture give us a wheel whose average life, as nearly as I can compute it, is about 30,000 miles, upon a time-table of *six miles* per hour! And this is a longer service than we have obtained from the wheels of any other manufacturer. Human life is not endangered by the breaking of a street car wheel, and we wear them much thinner than could be done on any steam road. We have had wheels taken out of our cars with the tread worn through, excepting $\frac{5}{16}$ of an inch.

My experience does not give the relative durability in practice of steel and iron rails. I have iron rails in our main line on Wells street. They are yet in fair condition after nine years' wear, but it is impossible to give the tonnage they have carried. I could give the number of car wheels that have passed over them, but not the general traffic or weight of passengers. I have steel rails in nearly as good condition under about the same tonnage. The time of service has been less, but the traffic greater. On the other hand, upon our Clark street main line, between Chicago avenue and the Viaduct, I had to take up the steel rails, equal in length to about two and a half miles, after four years and ten months' service. Our rail is denominated a "step rail." The car wheel travels on a head two inches wide on one side, and a tram three inches wide is provided for ordinary vehicles. About one-half the metal in the rail is in the head, which is one inch above the tram, but there is a groove in the tram $\frac{3}{16}$ of an inch deep. My car wheel flange is one-half inch in depth, and I have worn iron rails until the flange split the rail. The steel rails in question weighed originally 169,100 pounds: when taken out, 137,590 pounds—a loss of about 19 per cent., or say 5 per cent. per annum for the entire rail. The greater loss was in the head, and a number of heads I measured at random had worn down a half inch. These rails are fastened to the wooden stringer by counter-sunk head spikes $\frac{1}{2}'' \times \frac{1}{2}'' \times 5''$, twenty-two and a half inches apart. It is a wretched fastening, and does not prevent vibration. At the joint I now use a patent fastening, as described in a former paper, with satisfactory results. The vibration of the rails in question had

caused nearly every spike head to wear through the tram, and there was no way of fastening the rails, unless a special spike was made with a larger head and new counter-sinks bored in the rails, or entirely new holes bored intermediate between the original holes; for the municipal authority will not permit the spike head to project above the tram, as it would interfere with ordinary vehicles traveling upon the tram. One end of each rail *against the traffic* was battered. I got an estimate of the cost of cutting off this end and boring new holes, when the rail might have been again used. Old iron is in constant demand, and many inquiries are made for it. Not so old steel. No one ever solicited our old steel. I wrote to various parties. One offered $10 per ton, another $12.50, and I finally sold them for $12.75 per ton f. o. b. to a party who expected to use them in the track of a country road. I could have sold them far more readily and at a price 25 per cent. to 50 per cent. greater had they been of iron. I would state that these rails wore quite uniformly, not developing any imperfections of manufacture. At certain hours eighty cars pass over that portion of my line in *sixty minutes*, besides many vehicles whose number I cannot approximate.

The first cost of iron and of steel rails is now the same, and unless the steel wears enough longer to make up the difference in value as "old scrap," iron is the cheaper. I brought up this question of relative durability at the last convention of the American Street Railroad Association, but obtained little information. If I had steel rails side by side with iron rails, and one wore twice as long as the other, it would simply prove the relative durability of that steel and that iron. To judge intelligently, I must know the chemical constituents and the process of manufacture. Comparatively poor iron can be made into fair rails if thoroughly welded, and good steel can make poor rails if improperly rolled. We all know that iron may be good or bad, and steel the same.

This is a matter worthy of investigation, and I trust these few remarks may serve to bring out a full discussion from our members.

REMARKS ON WAVE REACTION.

By Walter P. Rice, Member of the Civil Engineers' Club of Cleveland.

[Read April 14, 1885.]

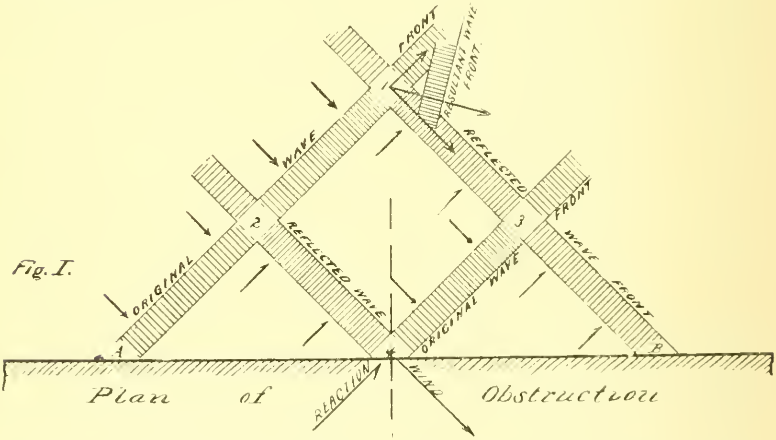
The modifications of waves by obstructions and resistances not only offer an interesting study, but one of great importance, as the success and efficiency of hydraulic works depends to a very large extent upon the nature of these wave modifications, under the conditions governing each particular case. It is not my intention in these remarks to attempt to give any explanation of the actual movement of the wave particles. Whether the theory that the particles of water oscillate in a vertical plane without advancing in a horizontal direction is correct, or whether the less accepted theory of Colonel Emy that the particles of water in a wave "are affected by a series of orbicular movements either simple or compound, whose intersections form the surfaces of the waves themselves," is correct, it would be presumption on my part to say; but I am

inclined to the belief that the latter theory, as I understand it, more nearly explains many of the wave phenomena, and further, that the orbits have an actual, though perhaps small movement of translation under favorable conditions. I shall, therefore, confine these remarks to wave movements in the general sense. It will be sufficient, therefore, to treat the apparent movements as real.

The phenomena of wave interference or back sea is produced naturally by steep, bluff shores and artificially by works of construction, such as breakwaters, piers, etc. The authorities state in regard to the extent of back-sea action, that "it ceases to be felt at a distance of about half a mile from the obstacle." I have every reason to believe that the action extends to longer distances—under favorable circumstances at least a mile. As a fact, the water-works crib, situated 0.8 of a mile from the lake arm of the Cleveland breakwater, had an iron door on the *south side* burst in by back seas after the construction of the breakwater, and lake captains give what would seem to me extravagant estimates as to the distance to which its effect is discernible in the handling of their craft.

From observation, the writer would offer the following explanation of reflected waves and the manner of their propagation. The peculiar phenomena of wave interference or back sea, in which the most noticeable features seem to consist of violent vertical oscillation, with wave fronts running in every direction and dancing crests, and in which there seems to be an entire absence of law—is, it seems to me, susceptible of easy explanation. Remembering that the reflection of water from a resisting medium follows the same laws as that of light and sound, an analysis is soon made.

Fig. I.



In the above figure if A 4 B represent a breakwater, pier or other resisting medium, and 1 2 A the incoming wave-front, then 2 4 and 1 3 B would represent the reflected wave-fronts, and the latter would travel along the hollows of the former, but with diminished velocity. The point 2 of the original wave-front having progressed to 4, the portion 2 A of the original wave has reached its *greatest elevation* along A 4 B and rolled away in the shape of the reflected wave 2 4. The original wave-

front 1 2 A has changed into the compound wave 2 4 3, and the portion 2 A into 2 4 the point 2 going to 4, and A to position originally occupied by 2. The condition being such that in the majority of cases the incoming waves strike the reflected ones endwise, as in the illustration, the forward motion or propagation of the reflected waves is but slowly overcome, and the two systems of waves mutually cut or intersect one another, each point of intersection forming a new wave front B B, and producing a crest exceeding in height that of the normal or incoming wave, by almost double. An inspection of the parallelogram of forces at 1 will show that the original simple disposition of forces rapidly becomes very complicated, and produces an inextricable confusion of wave-fronts, in which it is almost impossible to retain control of a ship and prevent her steering

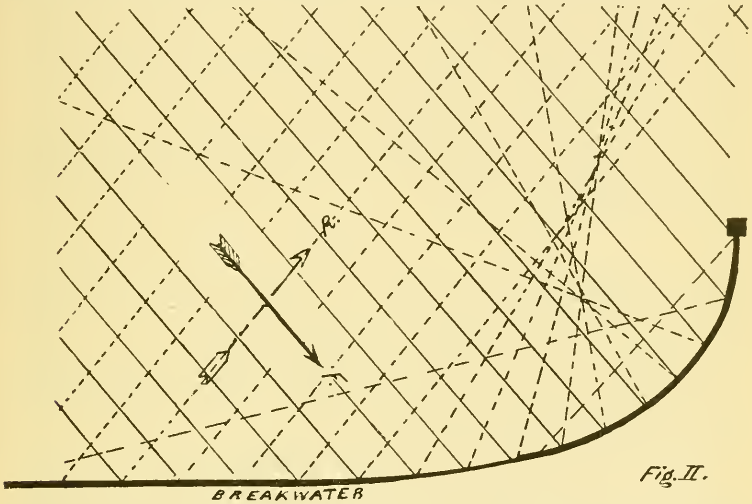


Fig. II.

badly, at the very time when a vessel has to be handled with the greatest skill and certainty, namely, on her entrance to a harbor. From personal observations I am satisfied that the above explanation of the *apparent* motions of the waves is the correct explanation of the *actual transmission* of *forces*, and I have on different occasions been able to clearly see and define the two principal wave motions, and detect some of their subsequent modifications, and to satisfy myself that reflected waves, or "back seas," may, under favorable circumstances, be propagated to longer distances than stated by the authorities.

Relation of Hydraulic Works to Back Seas.

Theoretically the most perfect formation of back seas would be caused by a perfectly smooth vertical surface. Further, Nature by the equilibrium which she establishes between the slope of shore lines and wave force and the effectual dissipation of wave energy by friction, would seem to favor designs having slope to seaward. It is true that a slope increases the ascensional power of the waves; but remember that it is destroying the vast energy converted into back seas by designs with vertical faces.

Essentials in the Design of an Ideal Breakwater for Comparatively Deep Water.

The following points would suggest themselves to me:

1st. That the waves should be met by a gentle slope to seaward, and that it should coincide with the *storm-developed* slope to the limit of depth attained by the maximum wave force.

2d. That the surface of the slope be as rough, irregular and jagged as possible, so as to create the greatest amount of friction.

A design embodying these features would, it seems to me, do away with the dangerous back seas. In breakwaters where, from the nature of the construction, back seas exist, some benefit might possibly accrue from the use of a curved entrance. I have roughly shown the effect of such a curve in Fig. II., which is to change the direction of the reflected forces and oppose them to each other, thus leaving the entrance or passage comparatively free from their influence, and confining the disturbance to areas not traversed by vessels. In the figure the full lines represent the direction of the original wave force or wind, and the dotted lines the direction of the reactions.

In conclusion allow me to remark that the opinions and statements in the above, if crude, have been given freely, and more in the hope of drawing out the opinions of those better posted and better able to elucidate than your humble servant.

The discussion following the paper on "Wave Reaction" was on the best forms for structures calculated to resist the action of waves, and naturally drifted into the subject of Shore Protection.

It was participated in by Messrs. Sargent, Eisenman, Strong, Rice and others, and various forms of piers and breakwaters were suggested, including floating breakwaters, and the failures and weak points of various expedients used for shore protection were noted.

One of the gentlemen spoke favorably of the common method of short pier jetties, running normal to the shore line and spaced at short intervals, while others believed that a V-shaped jetty with the point penetrating the shore would yield better results; as affording sharp entrance angles to the sand waves from any quarter.

The opinion was advanced that brush fascines, when properly constructed and retained, constituted a valuable, if not vital adjunct to any jetty designed for the collection and retention of sand.

Excellent results were claimed in the shape of beach formation by a style of construction consisting of piles about one-half foot apart, with top waling strips, and bottom wale near water line, the foot of piles being reinforced by fascines held down by rip-rap.

Vertical obstructions to wave action were deprecated in shallow water, as tending to cause a scour at the base.

RECENT SANITARY WORK AT THE UNIVERSITY OF VIRGINIA.

By Ernest W. Bowditch, Member of the Boston Society of Civil Engineers.

[Read April 15, 1885.]

Doubtless all know that the University of Virginia was founded through the efforts of Thomas Jefferson, about the year 1818. Previous to this date, however, there had existed what was known as Central College (now used as one of the professors' residences), afterward incorporated as part and parcel of the University.

I have indicated on this plan, the arrangement of the earlier buildings on the lawn, and East and West Ranges, as they are called. They were not all built at one time, and not all those that were planned for this locality have ever been completed, but for our purposes it will answer to consider those shown here as a unit.

The situation of the institution, near Charlottesville, Albemarle County, Virginia, 116 miles below Washington, at the junction of the Virginia Midland and Chesapeake & Ohio Railways, is almost ideal. At a high enough elevation in the well-known Piedmont region to be almost free from malaria, both aspect and prospect have been well considered in the placing of the various original buildings. Subsequent additions, bringing in widely different architecture and materials, have, to my mind, very considerably marred the general effect of the original mass, but a bird's-eye view is still very attractive. The buildings, without exception, are built of brick; most of them have slate roofs and interior finish of hard pine. They are also, for the most part, provided with basements, but rarely with cellars. The dormitories seldom have basements, and single floors are almost invariable everywhere. The general arrangement of the college buildings is rather unique—in fact, so widely different from that of any other institution of the kind with which I am familiar, that a brief explanation may be of interest.

It was originally intended by Mr. Jefferson that the professors should all be single men, and have their lecture rooms under the same roofs as their dormitories and living rooms. It soon proved, however, that this scheme was scarcely feasible, that the professors insisted on marrying, and therefore the plan was modified in so far as to have the lecture rooms located entirely in outside buildings.

The dormitories and buildings on the lawn are all joined by arcades, so that it originally was possible to go 1400 feet without going from under cover. This has been modified now, at the northern end of the lawn, where the arcades have been walled in and made into rooms. The east and west ranges are also joined from one end to the other by arcades, except at the alleyways. The professors' houses are placed at regular intervals on both sides of the lawn, and give great dignity to the central building, besides making possible a very thorough supervision of all dormitories on that portion of the grounds. The buildings occupied as hotels (commons) and by literary societies, take the place of professors' houses on the ranges, and attractive gardens separate the buildings on the ranges from those on the lawn. Two curiosities may here be men-

tioned—the brick garden walls and the old brick drains. The former, only four inches thick and some five feet high, are rendered very stable by being built like series of S's joined together at the top and bottom, and many of them, erected under Jefferson's own eye, are to-day in excellent preservation. The old brick drains, of which there appear to be several sets, resemble a huge cobweb in their alignment, and have, if the phrase be a proper one, grown up with the University. Some of them are stopped up entirely, very few have regular grades, and all are leaky.

The walls of the buildings are, as I said, built entirely of brick, foundations and all. To go a little more into particulars, it would be entirely within bounds to say that they are largely built of soft brick and laid up with lime mortar. In due process of time, by the action of the weather, the lime mortar has disappeared, so that below the surface of the ground it was in many instances possible to see through the walls where the plastering was torn down. Now these soft brick walls act like blotting paper in drawing moisture up by capillary attraction, there being no damp courses, and enough dampness is drawn up to wet the plastering of the rooms inside three and four feet high. Dormitories were found where the walls were so damp from this cause that the paper peeled off higher than the top of the beds. Every basement on the west lawn and west range was found to be exceedingly damp; in several there were very considerable water privileges after every storm. This may be explained by the fact that ledge comes to the surface in many places, and all of the basements are in rock excavation. No adequate drains being provided to carry off the surface or ground water, these basements have acted as tanks or cisterns, which accounts also, in a measure, for the damp walls. True, the houses were many of them provided with areas, but these were in no case deep enough, and pitched toward the building instead of away from it.

There is a tradition that the soil is clay, but from several months' observation it seems that the material is sometimes a marl, at others a decomposed bastard granite, and occasionally only a second quality of clay. That it is not genuine clay can be shown by the fact that water-pipe trenches dug in it do not, as a rule, hold water more than a few minutes.

The dormitories are, for the most part, rooms $10' \times 12'$, or thereabouts, with one window each, small open fireplace, and brick walls on all sides, low pitch roof immediately overhead, single hard pine floor raised from eight inches to one foot above the walk of the arcades at the front, and sometimes as much as three feet at the rear, though there is no definite rule about this. Occasionally, the floor is below the ground outside at the rear. Usually, there are holes for ventilation under the floors, both fore and aft, and sometimes in winter when the thermometer drops below zero the rooms are very cold indeed. Of course, it goes without saying that the doors and windows are many of them (after the fashion of collegians' surroundings) in a chronic state of smash, and consequently very draughty. The public water-closets and urinals were located at very considerable distances from many of the dormitories, so that there is constant temptation to the boys to adopt some modification of the old Mosaic law in the immediate neighborhood of their rooms. The

servants are all colored, which in those latitudes implies shiftlessness. so that many instances were found where chamber slops were regularly thrown underneath the chamber floors, or on the lawn just across the arcade in front of the door.

The drinking water for the portion of the University comprised in the west lawn and west range, is derived mostly from wells (numbered 1, 2 and 3) which, from their location and condition, were supposed to be more or less fouled, Nos. 1 and 3 particularly. Analyzed, during vacation, No. 2 showed pollution from an old cistern (now used as a cesspool), while Nos. 1 and 3 were in fair condition. For many years there has been considerable sickness of a zymotic type at the University that has been attributed entirely to the faulty condition of the old brick drains that run like cobwebs, here and there through the grounds. There seem to be at least three different and distinct sets of these old drains, and all were in leaky condition. One of the principal outfalls had been, till lately, just to the windward of the lawn, and the stench was at times very bad (hearsay). Careful investigation seemed to show that in those parts of the University where the trouble existed there were various matters, other than the drains, that needed attention, and that appeared to be quite as likely the source of sickness. The condition of things as found in portions of the suspected district, and to a less extent elsewhere, may be thus summed up:

Imperfectly drained land; imperfectly drained basements; faulty brick walls, and in consequence damp and wet plastering; insufficient and inconvenient sanitary arrangements; insufficient and impure water supply; inadequate and leaky sewers; wretched plumbing; very poor arrangements for care of rooms.

Briefly speaking, the land has been sufficiently drained, so that there is now not a single case of damp or wet basement in any building used as a dormitory, with two exceptions, where the changes are incomplete.

All damp and wet plastering has been made permanently dry, except in a few instances on chimney foundations, where it seemed hardly possible to change the conditions save at very great expense. Proper drains of Akron pipe have been provided for seven of the wettest basements, with excellent results. Houses have been jacked up, one after another, and new basements built with concrete floors, larger windows, with opportunities for additional sun and air, and hollow walls substituted for the old solid ones, wherever rebuilding was necessary. The old sewers, which may be said to have grown up with the University, have been discontinued and a new system of separate sewers, discharging at two outfalls instead of eight, have been built, and new plumbing, with proper grease-traps, etc., all thorougly ventilated, has been put in. The public water-closets and urinals have all been removed and replaced with latrines and slate urinals. Additional urinals have been built, and slop hoppers, with provision for proper flushing, have been arranged in every alley. The wells and cisterns have been thoroughly cleaned, made tight at the surface; the present gravity supply for washing and cooking has been supplemented by a Worthington pump, and work has just begun upon a system of water-works, to be owned jointly with the town of Charlottesville—a gravity system that will furnish 100 gallons per capita for 1,000 students, and double that if necessary.

This much has been accomplished during the past year, but more wants to be done.

The University of Virginia has for years suffered exceedingly from lack of funds. Used during the civil war as a barracks and hospital for the Confederate army of Virginia, it has had barely sufficient income since to maintain itself, without any expenditures on buildings not imperatively necessary. Before 1861, its students came from all over the South and West, a few from the North, and just previous to the breaking out of the war over 700 young men availed themselves of the educational facilities it afforded. Now most of the Southern States except Kentucky have State Universities, so that the Virginia and Kentucky students form by far the majority to-day at the University of Virginia.

The amount of money expended has not been great, as labor and materials are so cheap. About two miles of sewers have been built, new plumbing put in fourteen buildings, five buildings provided with new basements and areas built around seven ; boiler-house and boiler and six hundred feet of 4-inch cast-iron pipe have been laid, twenty-four new latrines, new urinals and slop hoppers with proper connections, and the total expense to date is $25,500. The best labor costs from 75 to 90 cents per day (60 cents per week to live), brick $3.25 to $4.00 per 1,000, and lay 13 to the cubic foot ; cement about the same as here, and sand higher.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 15, 1885:—A regular meeting was held and called to order at 7:50 P. M. Twenty-five members present.

In the absence of the President and Vice-President, Mr. C. W. Folsom was elected Chairman.

The record of the last meeting was read and approved.

The Chairman announced the death of Henry M. Wightman, a member of this Society. On motion it was voted: That the Government be requested to appoint a committee to prepare a memorial on the death of Mr. Wightman. The Government has appointed as that committee Joseph P. Davis, Clemens Herschel, Edward W. Howe.

Messrs. Elbridge L. Brown, Sumner R. Edmon and Arthur W. Hunking were proposed for membership respectively by Henry Manley and Alexis H. French; George R. Hardy and Walter Shepard; Fred P. Stearns and John R. Freeman.

Messrs. William A. Allen, W. Wendell Wright and H. D. Woods were elected members of the Society. The following resolution was presented and adopted:

Resolved, That the Boston Society of Civil Engineers looks with interest and with favor upon the project of a building in Boston for the joint use of scientific societies; and that it will be ready to co-operate in the consideration and discussion of such a project whenever and wherever it is presented in a tangible form.

On motion, it was voted: That the Government of this Society, if in its judgment it seemed proper, be instructed to confer with any society or committee intrusted with the furtherance of this project.

On motion, it was voted: That a vote of thanks be extended to Mr. Peter Schwamb for courtesies extended this society at its recent visit to the Massachusetts Institute of Technology, April 15, 1885.

Prof. William Ripley Nichols read a paper prepared jointly with P. E. Borden, Jr., on "The Chemical Analysis of Corrosion in a Cast-Iron Pipe from Fall River Water-Works."

Letters were read from Messrs. E. S. Chesbrough and G. A. Ellis regretting inability to be present at the last annual dinner.

Mr. E. W. Bowditch read a paper on Sanitary Work at the University of Virginia.

H. L. EATON, Secretary.

[*Adjourned.*]

VISIT OF THE SOCIETY TO THE LABORATORIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

On the afternoon of April 15, 1885, about twenty members of this society visited the Laboratories of Mechanical Engineering, Applied Mechanics and Mining Engineering at the Massachusetts Institute of Technology, and the shops used in connection with the Institute and the School of Mechanic Arts. The practical operation of a machine used for testing the transverse strength of wooden beams was shown by breaking a 4-inch by 12-inch oak beam 19 feet in length. Other apparatus used in testing engines and boilers, the slip of belting, etc., in the mechanical laboratory were shown by Professors Lanza and Richards. At the School of Mechanic Arts was shown the work done by the students in the carpenter's and model department, iron and brass molding, forging, chipping, filing and lathe work.

H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

MAY 13, 1885:—The 248th meeting was held at Washington University. President Moore called the Club to order at 8:20 P. M. There were 17 members and 7 visitors present. The unapproved minutes were read and adopted. The Executive Committee reported favorably on the proposal for membership of Walter S. Russell. He was balloted for and elected. Mr. Joseph T. Monell was proposed for membership by Messrs. W. B. Potter and J. B. Johnson.

The committee to consider the status of Civil Engineers in the employ of the United States made the following report:

Engineers' Club of St. Louis;

GENTLEMEN: Your committee to consider the status of Civil Engineers in the employ of the United States respectfully report:

That we find the question of the relation of Civil Engineers to the public works undertaken by the General Government was one of considerable prominence in the debates in Congress during the late session of that body, and is now in the public press. Also, that there is a general impression that the time has come for an increase in the numbers of the corps of Engineers sufficient to enable them to conduct the works under the present organization without employing civilians, or for a reorganization of that branch of the public service by which it shall be made a distinctively civil service.

Your committee is decidedly of the opinion that the best interests of the military service, as well as those of the civil engineering profession and of the country as interested in both these, demand that the latter alternative be the one pursued.

Your committee regrets to see the discussion of the subject in the public press turning aside from the broad question of creating an organization for the conduct of public works, which shall be equitable and just in distribution of rewards for merit, in promotion to higher rank and pay; which shall recognize the change in the condition of the engineering profession, both military and civil, since the days when both had to be imported from Europe, and which shall allow its engineers to come by judicious selection the same as judges are selected, from the ranks of a profession, and not from the roll of a single school.

To this question personal matters, past, present or future, the value of the different schools and mode of training, or the honesty and truthfulness inculcated through certain associations, are alike foreign.

There seems, therefore, to be need for a conservative influence, lest the utterances of individuals be taken as expressing the views and wishes of the engineering profession, and lest a discussion of a pure question of public policy degenerate into a controversy about matters of no consequence.

Other clubs than our own have taken up the consideration of the matter and have appointed committees. It has been suggested that these committees act together if possible through correspondence and conference, by representations, if practicable with a view to a joint memorial to express to Congress our view of the matter and a draft of the legislation required to carry that view into practical effect.

Your committee therefore asks to be continued, and for authority to confer with the representatives of other Engineering Societies, Clubs or Associations, with a view to concert of action, but without power to pledge this club to anything.

Respectfully,

ROBERT E. MCMATH,
J. B. JOHNSON,
H. S. PRITCHETT,
J. A. OCKERSON,
Committee.

By vote of the Club, the committee was continued and the authority asked was granted.

Mr. Frank H. Pond read a paper on "Pumping Machinery and Water-Works."

The paper was discussed by Messrs. Moore, Johnson, McMath and Seddon.

[*Adjourned.*] THOS. D. MILLER, Secretary.

MAY 27, 1885:—The Club met at Washington University at 8 P. M.

President Moore in the chair; sixteeen members and seven visitors present.

The minutes of the last meeting were read and approved.

The Executive Committee recommended that Jos. T. Monnell, proposed by Messrs. Potter and Johnson, be elected a Member of the Club. He was balloted for and elected.

Mr. Winslow Allderdice, of Akron, Ohio, was proposed for membership by Messrs. W. B. Potter and W. H. Allderdice.

A motion to hold a meeting of the Club, Wednesday, June 10, 1885, was carried.

Wm. H. Bryan read a paper on "Long and Short Stroke Engines," in reply to a recent publication.

The paper was discussed by Messrs. Baker, Allderdice and others.

Mr. W. H. Allderdice read a paper on "The Design of Receiver Compound Engines." The paper gave very complete mathematical discussion of the subject with blackboard illustrations. It was discussed by Messrs. Johnson, Baker, Moore and others.

Capt. J. H. Willard, of the Mississippi River Commission, was present, and gave some interesting facts concerning compound engines on Western river steamboats.

[*Adjourned.*] THOS. D. MILLER, Secretary.

JUNE 10, 1885 :—The Club met at Washington University at 8 P. M.

President Moore was in the chair, and twenty-four Members and five visitors were present.

The unapproved minutes were read and adopted.

The Executive Committee recommended that Winslow Allderdice, proposed by Messrs. Potter and Allderdice, be elected a Member of the club.

He was balloted for and elected.

The Committee also reported that in furtherance of the request of the Board of Managers of the JOURNAL of the Association of Engineering Societies, they have adopted the following rule :

Papers which are published in technical journals by procurement of the authors, will be considered as withdrawn, and will not be published in the JOURNAL.

Mr. Thos. McMath, of St. Louis, Mo., was proposed for membership by Messrs. M. L. Holman and S. F. Burnet.

Mr. Ockerson moved that when the Club adjourn it adjourn to meet at the call of the Executive Committee.

The motion was carried.

Prof. W. B. Potter, Chairman, read the report of the Committee on Smoke Prevention.

On motion, the Committee was continued, with the request that the matter presented be prepared for publication.

The subject was very generally discussed.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

MAY 19, 1885 :—The 209th meeting was held in the Society's Hall, at 4 P. M., President Williams in the chair.

The minutes of the preceding meeting were read and approved.

In the absence of the Secretary, Mr. Liljencrantz was appointed to act as Secretary *pro tem.*

Application for membership was received from Prof. H. B. Herr, of Chicago Ill., indorsed by Messrs. Liljencrantz, Draper and B. Williams.

On motion, the Trustees were authorized to dispose of such furniture belonging to the Society as will not hereafter be required.

[*Adjourned.*] G. A. M. Liljencrantz, Secretary *pro tem.*

CIVIL ENGINEERS' CLUB OF CLEVELAND.

ANNUAL ADDRESS OF PRES. J. F. HOLLOWAY BEFORE THE CIVIL ENGINEERS' CLUB OF CLEVELAND, MARCH 10, 1885.

It has been the custom at our annual meetings, for the President to make a somewhat extended review of engineering progress during the year past, not only in our immediate vicinity, but in the country at large.

For various reasons, but principally that we may have more time to devote to other, and more agreeable exercises that are to come later, I purpose to omit any extended remarks upon that topic at this time. It is with much pleasure that I announce, that the growth and progress of the club has been constant, and satisfactory. The total number of members is now 134; of that number 17 have been added during the past year, and one member, Mr. John Crehore, has died. When you take into account the short space of time in which the club has had an existence, and also the fact, that previous to that time there had been no organization by which members of our various professions had been thrown together, or by which they were enabled to make the acquaintance of each other, the result as now shown is exceedingly satisfactory, and reflects great credit upon the few members who were in the main instrumental in its formation. But I have not alone to congratulate you on the material progress you have made, both as to membership, financial standing, and the social eminence you have attained, but also as to the practical and scientific value of the papers that have been read during the past year, and the discussions thereon: all of which are shown forth in the pages of The Journal of the Association of Engineering Societies. It will be proper for me to make mention of the fact also, that the Association of Engineering Societies, the formation of which was the result of the action taken by this club nearly five years ago, and during which time we have been so ably represented in its management by our member, Mr. M. E. Rawson, has never been in better condition than now. During the past year two more societies have become members of the organization, the Engineers' Club of Minnesota, and the Civil Engineers' Society of St. Paul, and still another Western society has made overtures for admission. It is yet too early to say just what effect this increased membership will have; but it is safe to believe it will result in increasing the interest of the Journal, and of decreasing its cost to its membership.

During the year, as I before said, the club has suffered the loss of one of its highly esteemed and valued members. While not a particularly strong man physically, until in answer to an outstretched hand which beckoned him "to come up higher," Mr. Crehore seemed a year ago as likely as any one to take his place here to-night. To the beautiful and

touching eulogy paid to his memory by our valued member, and his warm personal friend Professor Stockwell, no words of mine can add a single unexpressed loving thought; but permit me to suggest, that hereafter in our yearly membership list there be added the names of those who have "passed over to the other side." It seems to me, that as years go on apace, those who are left, will turn now, and then, with loving hearts and fond remembrances, to the page whereon shall be recorded our honored dead; and may we not all feel, in the consciousness of that record that shall await us "after life's fitful fever is o'er," a new inspiration that shall aid us in making our lives more worthy, more useful, and more helpful to all about us. While I did not intend at the outset to refer to any engineering achievements, there has come to my knowledge one that must, I think, interest you all. Standing a few days ago in the midst of a large industrial works, surrounded with evidences of unusual activity, I was led to inquire as to its cause. I was told that they had just received a cablegram from the English government ordering a number of extra large, and powerful steam pumps, such as are in use in this country for pumping oil from the wells to the seaboard. These pumps are to be placed along a pipe line from the Nile River across the desert toward the Soudan, for the relief, and sustenance, of the English army now in Egypt; which, in addition to the danger of confronting the hordes of the "False Prophet," must very soon meet the added danger of a tropical sun's heat, on arid plains where no wells are to be found, and where no fountains flow to slake a thirst which, otherwise, must waste as a plague by day and by night. Standing there amid the whirling wheels and revolving spindles of an engineering workshop, busy on such an errand of mercy, I could not but feel proud of my country, and of my profession; and in my fancy I saw standing on the banks of that ancient river, whose waters once cradled the childhood of not only the world's greatest law-giver, but engineer as well, an American engineer, planting there the invention of an honored though dead citizen, which, when completed, he would touch, as did Moses with his rod, the rock at Meribah, and now, as then, there will leap forth a flood of life-giving water which shall burst out anew on every plain, and in every camp, above which in the sultry air shall float the cross of St. George. While war at best is full of horrors, I have thought possibly there might grow out of this new and untried expedient for its prosecution, something of value in more pacific times. It may be that from that long line of black pipes, which like a huge serpent will stretch itself across the desert sands, there will come here, and there, drops of crystal water, which, falling on soil barren for a thousand years, will find hidden germs therein that shall spring into new life and beauty, thus making in reality the "desert to blossom as the rose," and also showing what, by the aid of the engineer and his inventions, may be done in reclaiming a land now worthless, but which was once famous for its fertility. Did time permit, I would gladly go on and illustrate how, in a thousand ways, the genius, the skill, and the industry of the inventor, and engineer, has contributed to the advancement of science, art and civilization. As the years move on, the world's indebtedness to our profession is being more generally recognized;

and as the warriors and conquerors of the olden time fade out of remembrance, it is the man of thought, and study, that is taking their place. Where, amid all the triumphal arches, and monuments, reared to perpetuate a warrior's name, or battles fought, is there one so held in universal esteem as that of James Watt, the engineer, beneath which, in letters of enduring granite, are these words of Lord Brougham :

> "Directing the force of an original genius,
> Early exercised in philosophical research
> To the improvement of the steam engine,
> Enlarged the resources of his country,
> Increased the power of man,
> And rose to an eminent place
> Among the most illustrious followers of science
> And the real benefactors of the world."

ENGINEERS' CLUB OF MINNESOTA.

March 13, 1885 :—Regular meeting called to order by the President, eighteen Members being present.

The new committees on Lighting, Heating and Ventilation, on Electrical Engineering and on Miscellaneous Matters, were announced by the President.

The President was made *ex-officio* member of all the committees.

Messrs. Walter Pardee and D. P. Walters were elected members of the Club, and the following gentlemen were proposed for membership : H. W. Morell and C. B. Asken by J. H. Woolsey, and Jas. Waters and F. L. Stran by L. H. Baker and W. W. Redfield.

Prof. Pike invited the Club to witness some tests of materials at the University on Friday, March 27, and afterward to meet socially at his house, which invitations were accepted.

The Club then took up the subject for discussion, "The New Central Bridge over the Mississippi—What and Where Should it Be ?" This matter was very generally discussed, and finally it was voted that the Club indorse the decision already arrived at, namely, to build a stone arch bridge 80 ft. wide on the site of the Suspension Bridge.

[*Adjourned.*] Wm. A. Pike, Secretary.

April 10, 1885 :—Regular meeting, nine Members being present.

In the absence of the President and Vice-President, Mr. James Waters was elected President *pro tempore.*

The records of the last meeting were read and approved.

Messrs. F. L. Stran, H. W. Morell and C. B. Asken were elected Members of the club, and the following gentlemen were proposed for membership : R. H. Sanford by Wm. A. Pike and James Waters, C. F. Terney by James Waters and A. C. Libly, J. H. McNulty by W. W. Redfield and Wm. A. Pike.

Mr. Pike then read a paper upon "Some Tests of Materials Made at the University of Minnesota," which was discussed.

[*Adjourned.*] Wm. A. Pike, Secretary.

May 8, 1885 :—Regular meeting. In the absence of the President, Vice-President Abbott presided, thirteen Members being present.

The records of the last meeting were read and approved.

Messrs. R. H. Sanford, C. F. Terney and J. McNulty were elected Members of the club.

Mr. James Waters read a paper upon "Pumping Machinery versus Reservoirs," which was generally discussed.

On motion of Mr. De la Barre, the Chair appointed Messrs. De la Barre, Pike and Newman to consider the advisability of an excursion for the members of the club and their families.

[*Adjourned.*] Wm. A. Pike, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

DYNAMOMETERS.

BY C. F. WHITE, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read April 29, 1885.]

Power measurement has been carried on ever since prime movers have been employed, and the great variety of devices for such measurement are but different forms of dynamometers.

The friction-brake and the indicator represent two classes of power measuring machines in very general use. But the word dynamometer is acquiring a narrower and more technical meaning, so that at present it most often means a machine for transmitting and, at the same time, measuring power. Hence the full name, transmitting dynamometer.

The demand for this class of instruments has increased with the movement toward centralization in development of power, and also with the growing call for a more exact knowledge of the power required for various kinds of work. Members of our club have informed us of the excellent appliances at hand for the measurement of gas and of water, and I am glad to call your attention to several recent forms of power-meters, fully equal, I believe, in convenience and accuracy to gas or water meters.

Right here I ought to say that most of the dynamometers which I shall mention have been described at different times in technical and engineering journals. A short review of their leading features will not, I believe, be amiss.

In a transmitting dynamometer some element of a train of mechanism is deviated from its normal position by the force transmitted. This deviation is resisted and measured by weights or by springs.

If three gear-wheels be run together, there is an effort exerted on the axis of the intermediate one, tending to move it out of position.

When power is transmitted by a pulley, the arms bend more or less from their original shape.

One part of a belt is tightened, and another part relaxed, by the transmission of power through it.

In that form of transmitting dynamometer devised by Wm. Kent,

M. E., the shaft carrying the intermediate gears is arranged as a pendulum, and in its normal position hangs vertically. The force transmitted through the box-mitre-gears swings this pendulum from the vertical. This swing movement causes a pencil to traverse a paper-drum having a motion at right angles with the pendulum plane, and proportional to the speed of the gear-wheels. A suitable clock-work marks equal intervals of time on the paper. From the diagram thus produced, the intensity of

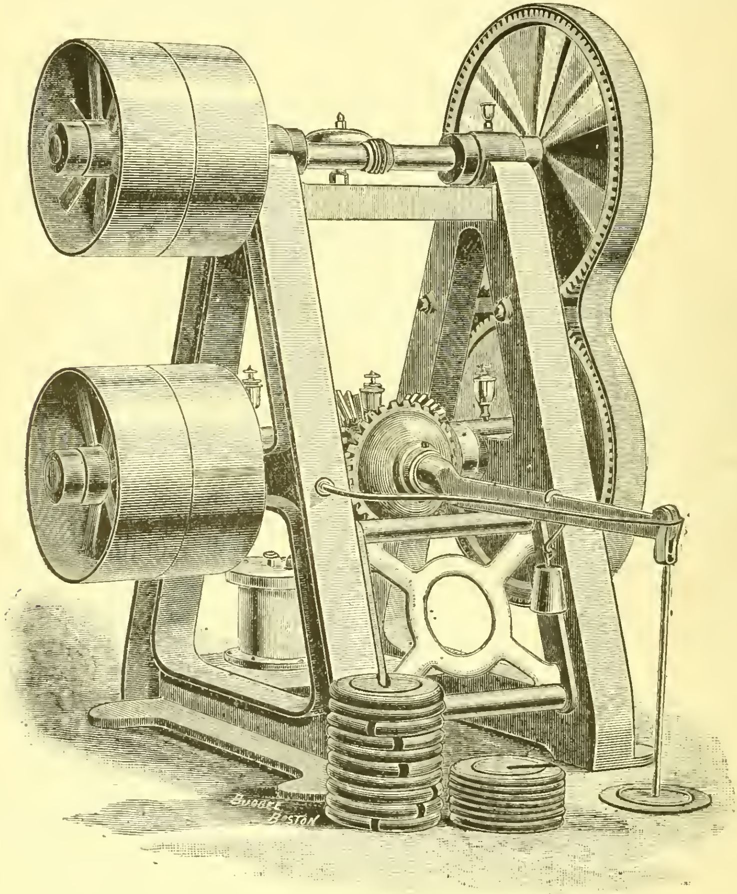


FIG. 1.

the force and the distance through which it has acted may be read and the power determined.

The "Improved Balance Dynamometer"* (Fig. 1) also uses as the deviating element box-mitre-gears. A double-letter "A" frame carries across its top a shaft on which, at one end, is a large spur-wheel, at the other tight and loose pulleys. Across the centre-bars of the frame extend the two

* Made by Lawrence Machine Shop, Lawrence, Mass.

gear-shafts, one of which has a spur-gear, and the other tight and loose pulleys exactly like the upper shaft. The arm carrying the intermediate mitre-gears is prolonged into a scale-beam. The tendency of this beam to rotate, when transmitting power, is overcome by weights hung to it. A small gong is struck at the end of each hundred revolutions of the shafts. The scale weights are so stamped that by dividing the number on them by the number of seconds to each hundred revolutions times the equivalent of a horse-power in foot-pounds per second, the horse-power transmitted is obtained :

$$\frac{\text{Stamp.}}{\text{Seconds to 100 rev.} \times 550} = \text{H.P.}$$

Mechanism for giving a continuous record may be used, if desirable.

The apparatus brought out by Hamilton Ruddick* (Figs. 2 and 3) consists of a sleeve secured to the shafting carrying on opposite sides radial arms. Loose upon this sleeve is a pulley having a pair of arms similar to those just mentioned. Between the ends of these arms springs are placed, which

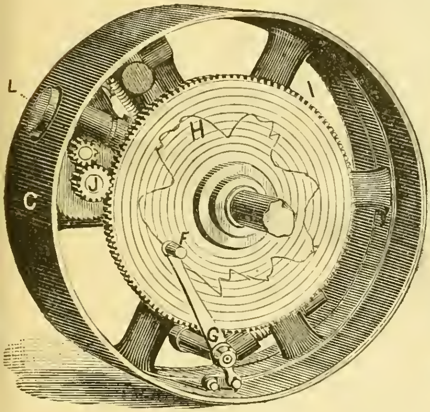


FIG. 2.

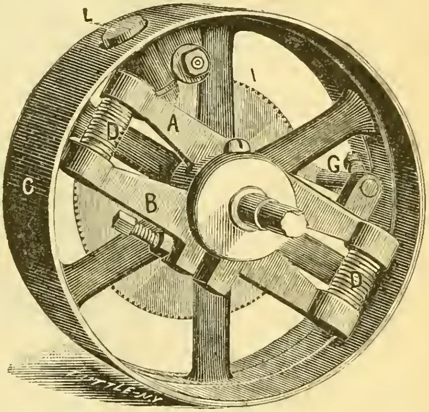


FIG. 3.

are compressed proportiontionally to the force transmitted from shaft to pulley, or vice versa. A pencil arm, pivoted on the sleeve and connected with the pulley by a link, moves, with the compression of the springs, across the face of a flat paper disk ; and by its distance from the zero line indicates the intensity of the force transmitted. Motion of rotation is given to the disk by means of a differential gearing, actuated by a ratchet and a stud, which, projecting through the rim of the pulley, is moved once at each revolution by the belt pressure. By a suitable adjustment of the gears, the disk may be made to revolve in any desired period of time, and from the distance through which the disk has moved a record of the number of revolutions is had.

Another transmitting dynamometer † designed by F. Van Winkle (Fig. 4), has been recently put upon the market. A strong cast-iron plate is strapped to the arms of the transmitting pulley, the pulley being loosened upon

* Made by Transmitting Dynamometer Company, 47 Astor House, New York.

† Made by Franklin Van Winkle, M. E. 22 Cortlandt street, N. Y.

the shaft. A second plate with a long hub is placed near the first, centred about and secured to the shaft by set screws. A pair of tension springs transmit the motion of one plate to the other, and are elongated in proportion to the load. The movement of the plates past each other becomes the measure of the transmitted force, and by means of a steel ribbon and suitable pulleys causes the hand on a stationary dial plate hanging from the long hub to move. The machine is so adjusted that, the diameter of the pulley and the number of revolutions being known, the horse-power is read off at once. Continuous record attachments are also made for the instrument.

The "Emerson power scale"* is a rotary transmitting dynamometer (Fig. 5) by which the load is weighed with weights and levers, as in a common

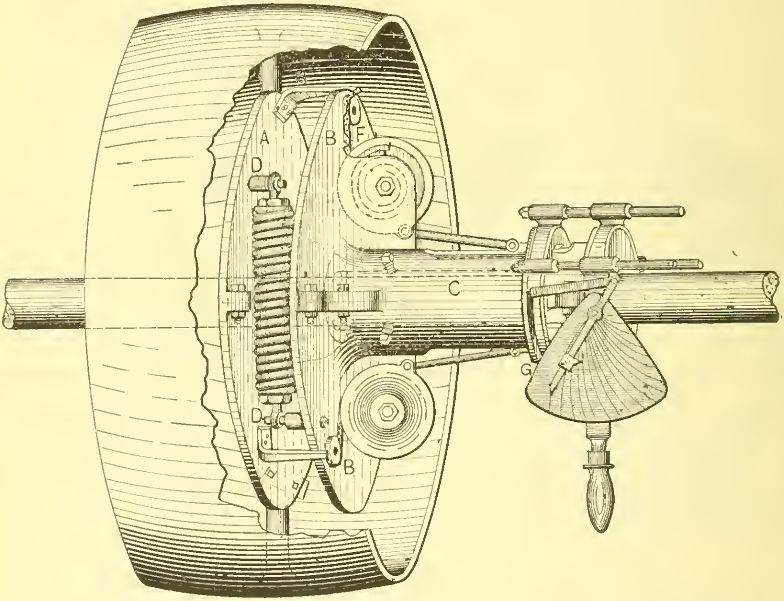


FIG. 4.

scale. A circular frame, or "spider," with a long hub, is secured to the shaft close up to the driving pulley. Around this spider is a rim free to rotate, and from which studs project and serve to connect it to the pulley. In transmitting power from the shaft to the (loosened) pulley, the tendency of the rim to rotate on the spider is resisted by a system of levers which communicate with a pendulum balance weight.

As the system of levers receives the transmitted force at a known distance from the centre of rotation, the distance traversed per revolution is known. A speed-counter shows the revolutions, so that the force indicated by the pendulum times the number of revolutions per minute times the constant, divided by 33,000, is the horse-power.

$$\frac{\text{Reading of scale} \times \text{rev. per. minute} \times \text{constant}}{33{,}000} = \text{the H.P.}$$

* Made by Emerson Power Scale Co., Lowell, Mass.

In reviewing briefly the machines described, the Kent and the Lawrence dynamometers form a class by themselves, as both are independent apparatus requiring setting up and special belting. Each machine is capable of being adjusted to do all that the other will do.

Of the three rotary dynamometers, the Ruddick stands somewhat alone, from the facts that it must replace the usual driving pulley and readings can be taken only when at rest. It is, however, very compact, and furnishes a convenient record sheet from which both force and distance can easily be read.

The Van Winkle and Emerson machines have in common certain

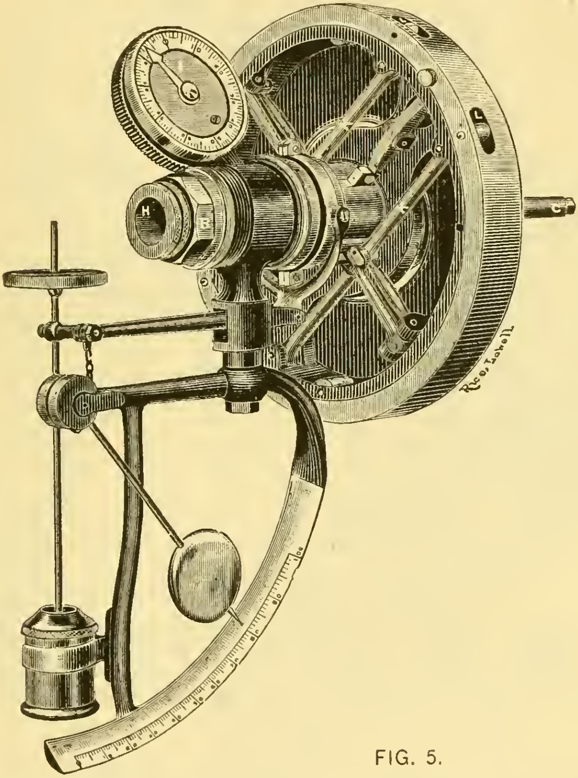


FIG. 5.

features which recommend them highly for some classes of work. Both are so made (split) that they can be put on a shaft alongside the regular pulley without disturbing pulley or belt, save loosening the set screws. The dial plates hang quietly from the shaft, and the power may be read off at any moment.

In all of the dynamometers which we have just noticed, the record is made in a direct ratio to the force transmitted, and upon a scale not readily changed.

By the kindness of a friend, I am able to present to you to-night the details of a new transmitting dynamometer which have not before been brought

before the engineering public. The apparatus has a number of interesting features, and I ask your attention to its construction, the theory on which it is based, and to its performance under severest tests.

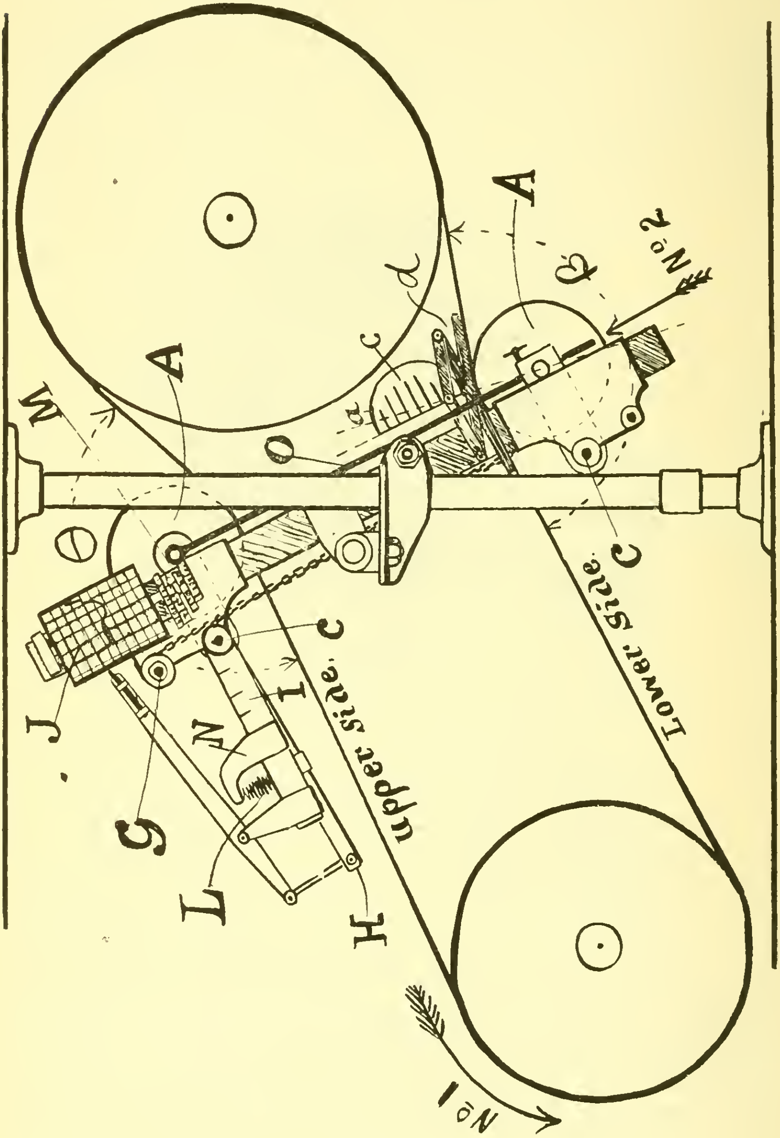


FIG. 6.

This new dynamometer, which is sold under the name of Wales' Portable Dynamometer,* makes use of the difference in tension in the two parts

* Made by Denton & Graydon Manufacturing Co., 15 Liberty street. New York.

of a belt transmitting power (Fig. 6). Two rolling pulleys AA swing upon pivots CC, which are supported in castings DD. The castings slide upon the bar E, so that by means of the chain F and the winding drum G the pulleys AA may be drawn together, causing the belt to contain the angles φ and β. These angles, being made equal in adjusting the instruments, the tension of the belt when at rest is the same on either side, and causes equal pressures on each of the rolling pulleys, tending to force them apart, but being prevented from doing so by the tie-rod O.

When motion occurs in the direction of arrow No. 1, any transmission of power from the lower pulley to the upper one causes an increase in tension along the "upper side" of the belt and a decrease of tension along the "lower side." The difference of tension thus caused between the two parts of the belt forces the rolling pulleys and the tie-rod O to swing about the points C C in the direction of arrow No. 2. The latter action causes the arm H to move out of parallelism with the arm I, to which is fixed the bracket N. This movement extends the spring L until its resistance counteracts the pressure on A A, due to difference of belt tension. The movement of the arm H causes the pencil X to move outward upon the paper drum J. The latter is given a motion of rotation by means of a train of differential gearing M driven from the arbor of one rolling pulley. The combined motions of the pencil and the paper result in the tracing of a line, the height of which represents the force transmitted by the belt, and the length of which represents the length of belt passing over the rolling pulley during the time of the experiment. An inch of height of this pencil line will represent different amounts of belt tension, according to the value of the angles φ and β, and also according to the distance from C of the spring L, the spring being arranged to slide to four positions along the arms H and I. Consequently, by a proper selection of value for the belt angle and for the position of the spring, the pencil can be made to move through its maximum height for any amount of power measured. The following table exhibits the range of the instrument for various values of belt angle and position of the spring.

The table gives the horse-power represented by one inch height (or rise) of pencil line per thousand feet of belt travel per minute.

The figures in the first column are readings of an angle-gauge supplied with the instrument, and specially adapted to the measurement of the belt angle. The gauge is shown in the cut at a d c applied to the belt.

The graduations are made to represent the ratio of the tension along the belt, to the component of this tension acting along the line joining the centres of the rolling pulleys.

Directions for using are engraved upon it.

Measurement of belt speed is had in two ways :

1. By timing the revolutions of the primary gear-wheel. The primary wheel of the train giving motion to the paper drum is graduated to serve as a speed counter, each revolution of the wheel representing one hundred revolutions of the rolling pulley. The circumference of the latter, for single belting, is exactly two feet. Hence each revolution of the primary gear-wheal represents two hundred feet of belt-travel.

TABLE.

Reading of Angle-Gauge.	Position of Spring.			
	Mark 1. H.-P.	Mark 2. H.-P.	Mark 3. H.-P.	Mark 4. H.-P.
1.	9.08	4 01	1.998	0.936
2.	4.54	2.02	0.896	0.468
2.5	3.63	1.61	0.717	0.374
3.	3.02	1.34	0.597	0.312
3.5	2.59	1.15	0.512	0.267
4.	2.27	1.01	0.448	0.234
4.5	2.02	0.896	0.398	0.208
5.	1 81	0.806	0.358	0.187
5.5	1.65	0.733	0.326	0 170
6.	1.51	0.672	0.299	0.156
6.5	1.40	0.620	0.275	0.144
7.	1.30	0.576	0.256	0 134
7.5	1.21	0.537	0.239	0.125
8.	1.13	0.504	0.224	0.117
8.5	1.07	0 474	0.211	0.110
9.	1.008	0.446	0.199	0.104
9.5	0.955	0.425	0.188	0.100
10.	0.908	0.404	0.179	0.094

2. By measuring the length of the diagram. The differential gearing is so arranged that one million two hundred and fifty thousand revolutions of the rolling pulley cause one turn of the paper drum. The latter is twelve and one-half inches in circumference ; consequently, each inch of length of a diagram measured parallel to the base-line represents twenty thousand feet of belt-travel.

The expiration of each minute is recorded on the diagram by a telegraph sounder carrying a pencil which bears on the paper, and which is caused to make a stroke once a minute by the passage through a mercury cup of the hand of a minute clock placed in battery curcuit leading to the sounder.

An inspection of the table of horse-power shows the extraordinary range of the instrument. It will be seen that the scale of the diagram may be varied so that an inch of pencil motion may represent ninety-four one-thousandths of a horse-power, or ten times this amount at one thousand feet per minute belt speed. The maximum rise of the pencil is five inches. Hence, at the same belt speed, five inches of pencil motion could be produced by forty-seven hundredths of a horse-power with a belt angle of about one hundred and twenty degrees, and the spring close to the rolling pulley ; or five inches rise could control forty-five and four-tenths horse-power with a flat belt angle, and the spring at its farthest position on the arm H.

At electric light belt-speed of four thousand feet per minute, five inches of pencil motion would control thirty horse-power with the spring at position one and a moderate belt angle ; while with the spring at four about half a horse-power would move the pencil an inch. So that the full power of a thirty-light dynamo on the one hand, or the power needed to merely overcome the friction of its journals on the other, could be recorded on a sufficiently magnified scale to insure accuracy.

This extraordinary range of capacity is due in a measure to the influence of the belt angles, but the principal cause is found in the fact that

the movement of the spring affects the pencil scale as the *square of the distance* of the spring from the centre of the rolling pulleys. This will become apparent from a consideration of the appended statement of the theory of the instrument.

Let T = tension of the belt when at rest.

" $\Delta\ T$ = increase of tension on "upper side" = the decrease on the "lower side;" whence the resultant pressures upon the rolling pulleys are:

$2\,(T + \Delta\ T) \cos. \frac{\theta}{2}$ for "upper side" acting in the direction $f\ B$ bisecting θ.

$2\,(T - \Delta\ T) \cos. \frac{\beta}{2}$ for "lower side," acting in the direction $b\ R$, bisecting β.

If α be the angle between the tie-rod (o) and the bisecting lines $f\ B$ and $b\ R$, then the above pressures resolved along the direction of the tie-rod are:

$\left[2\ (T + \Delta\ T) \cos. \frac{\theta}{2}\right] \cos.\ \alpha$ for "upper side" in direction $o\ B$.

$\left[2\ (T - \Delta\ T) \cos. \frac{\beta}{2}\right] \cos.\ \alpha$ for "lower side" in direction $o\ R$.

The difference between these two pressures is, putting $\theta = \beta$, $4\ \Delta\ T \cos. \frac{\beta}{2}\ \cos.\ \alpha$ acting in the direction of arrow No. 2, and it is this amount of force which causes the rolling pulleys and the tie-rod to swing about ($C\ C$) and extend the spring. The angle gauge is made and graduated so that if applied with the arms a along the belt and with the graduated plate so held that its straight edge is parallel to the tie-rod, the reading is equal to $2 \cos. \frac{\beta}{2} \cos.\ \alpha$.

Let this be represented by A. Then we have that $2\ A\ \Delta\ T$ equals the force acting in the direction of arrow No. 2. But, $2\ \Delta\ T$ equals the difference of the tensions on the two sides of the belt; hence the reading of the angle gauge is the ratio of the difference of belt tensions, to the component of this difference acting along the line joining the centres of the rolling pulleys.

We have, that the moment of $2\ A\ \Delta\ T$ about c must equal the moment of the resistance of the spring about c.

To obtain the latter, let—

S = scale of the spring, or load in pounds required to extend it one inch.

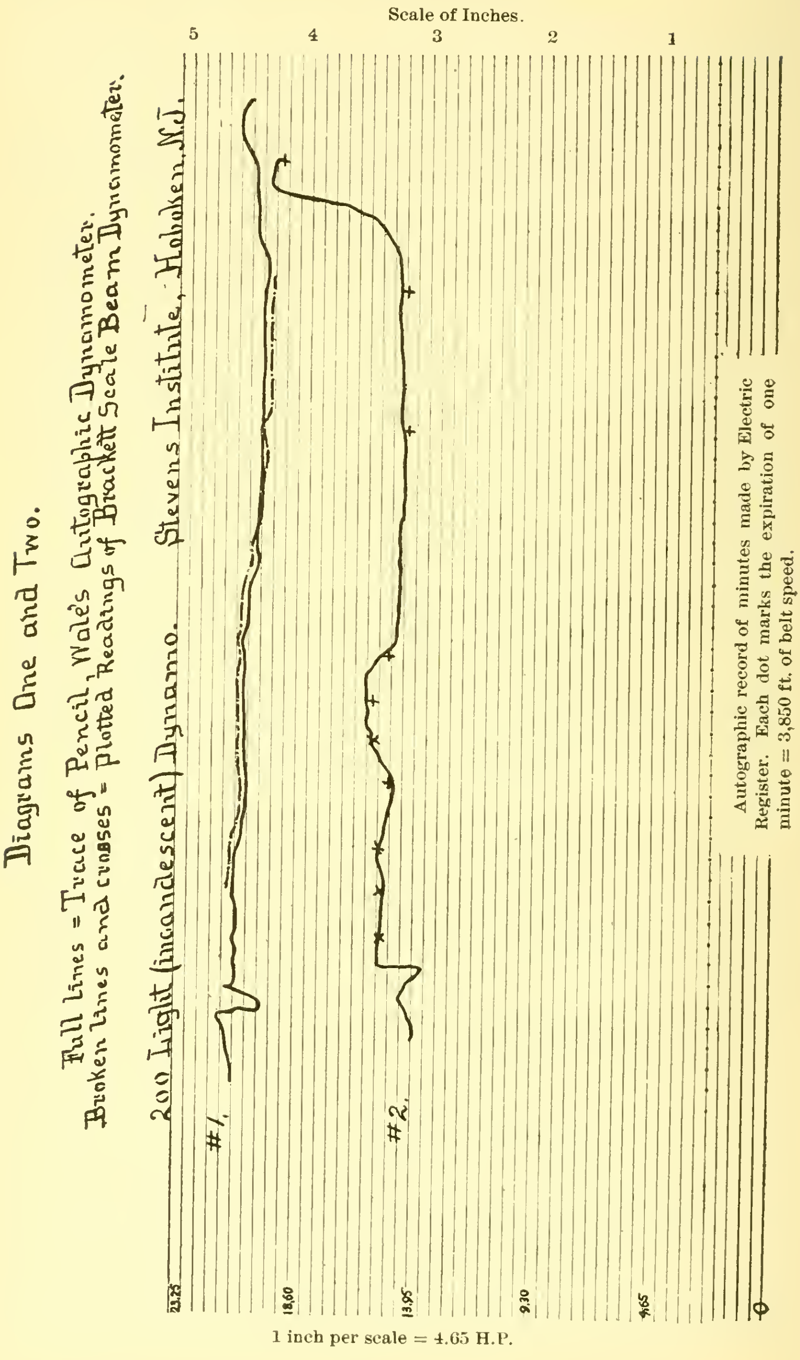
$l = C\ R = C.\ \beta\ B$ = lever arm of the force $2\ A\ \Delta\ T$ about c.

$X = C\ N$ = lever arm of the spring about c.

$L = C\ H$ = lever arm of primary point H of the pencil motion.

ρ = ratio of movement of H to movement of pencil point.

Then for h inches rise of the pencil the point H will move $\frac{h}{\rho}$ inches, and hence the spring will extend $\frac{X}{L} \cdot \frac{h}{\rho}$ inches, whence the resistance


Diagrams One and Two.
Full lines = Trace of Pencil, Wale's Autographic Dynamometer.
Broken lines and crosses = Plotted Readings of Brackett Scale Beam Dynamometer.
200 Light (incandescent) Dynamo.
Stevens Institute, Hoboken, N.J.
#1.
#2.
Scale of Inches.
5
4
3
2
1
23.25
18.60
13.95
9.30
4.65
0
Autographic record of minutes made by Electric Register. Each dot marks the expiration of one minute = 3,850 ft. of belt speed.
1 inch per scale = 4.65 H.P.

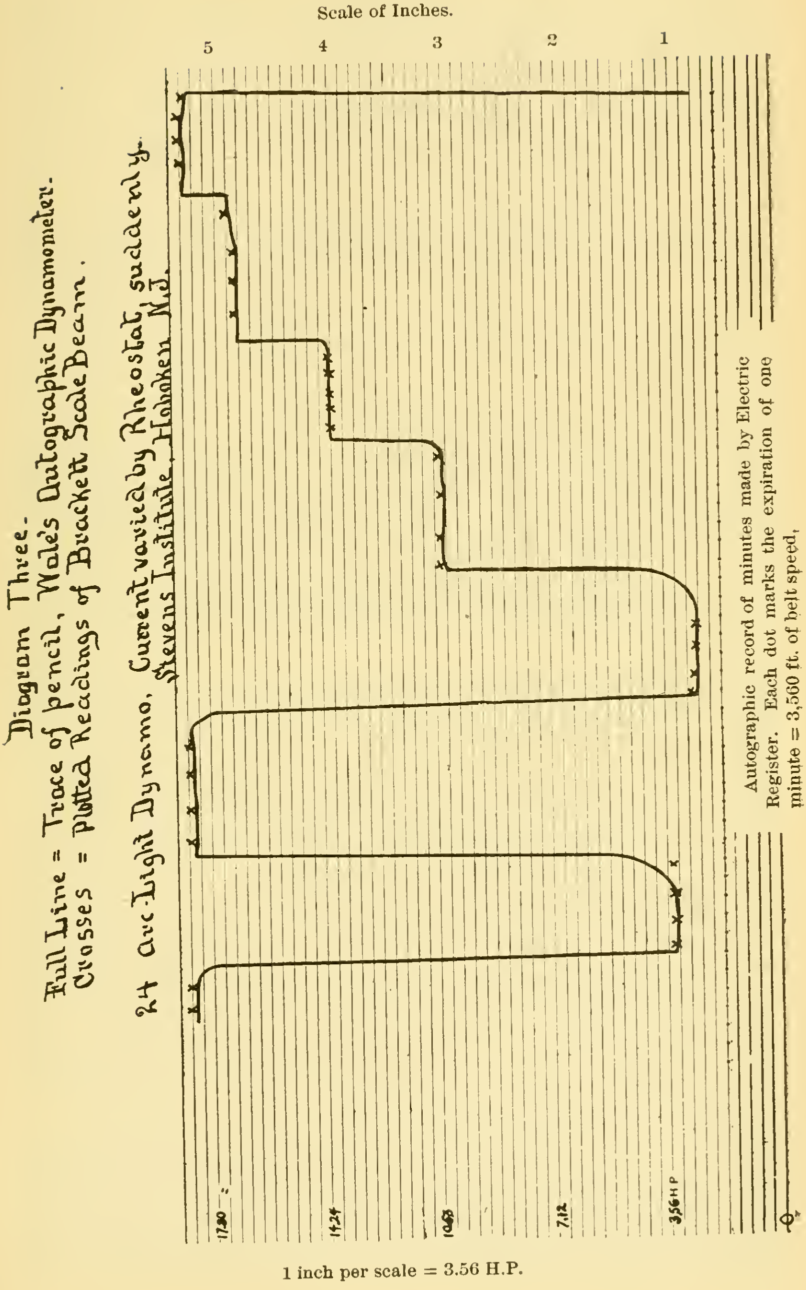


Diagram Three.
Full Line = Trace of pencil, Wale's Autographic Dynamometer.
Crosses = Plotted Readings of Brackett Scale Beam.
24 Arc-Light Dynamo, Current varied by Rheostat, suddenly.
Stevens Institute, Hoboken N.J.
Scale of Inches.
5
4
3
2
1
17.80
14.24
10.68
7.12
3.56 H.P.
Autographic record of minutes made by Electric Register. Each dot marks the expiration of one minute = 3,560 ft. of belt speed.
1 inch per scale = 3.56 H.P.

will be $S \cdot \frac{X}{L} \cdot \frac{h}{\rho}$ pounds, and the moment about C of this resistance will be $X\left(S \cdot \frac{X}{L} \cdot \frac{h}{\rho}\right)$ inch-pounds, which must equal the moment l $(2\ A\ \varDelta\ T)$ inch-pounds. Or we have: $X\left(S \cdot \frac{X}{L} \cdot \frac{h}{\rho}\right) = l\ (2\ A\ \varDelta\ T)$; whence the difference of tension represented by any height of the pencil, as h, is $2\ \varDelta\ T = \frac{S\ X^2\ h}{A\ l\ L\ \rho}$ pounds.

The power transmitted will be, the belt travel times the difference of tension, or if $B =$ the belt travel in feet per minute, then the power in foot-pounds $= 2\ \varDelta\ T\ B$. The horse-power $= \frac{2\ \varDelta\ T\ B}{33{,}000} = \frac{B \cdot S \cdot X^2\ h}{A\ l\ L\ \rho \cdot 33{,}000}$, or per one inch rise of pencil, the horse-power $= \frac{B \cdot S \cdot X^2}{A\ l\ L\ 33{,}000}$, or a constant times $\frac{B\ S\ X^2}{A}$. And it is the value of this constant which is given in the table, B being expressed in thousands of feet. It is evident that the scale of the diagram varies as the *square* of the distance of the spring from C, and this fact is the principal cause of the great range of the instrument, which is such as to render the power transmitted per unit of weight of apparatus greater than any form of dynamometer yet devised.

TEST OF ACCURACY OF WALES' DYNAMOMETER.

The following rigorous test of the instrument was made in the Department of Experimental Mechanics, Stevens Institute of Technology, Hoboken, N. J.:

The dynamometer was arranged upon a vertical belt, driving a large dynamo on the floor above. The dynamo was supported by an iron U-shaped cradle, hung upon knife-edges. Steel plates on wooden frames carried the latter. The axis of the dynamo-shaft and the bearings of the knife-edges we adjusted so as to be precisely in the same horizontal line. Thus the cradle and the contents were entirely free to oscillate about the axial line, and being delicately counterpoised, the centre of gravity of the entire mass was brought nearly into this axial line. Under these conditions a very slight force applied to the dynamo on a line *not* passing through the axis, as at the circumference of the driving pulley, would cause a sensible vibration of the scale beam attached to the cradle, so that by applying weights to this beam the force exerted by the belt could be accurately weighed. The driving force being thus determined, the horse-power expended at the dynamo became known by observing the rotative speed of the spindle. This was measured by a speed-counter attached to the spindle, and so manipulated that the revolutions were determined within one-third of one per cent.

This method of weighing the power of a dynamo, which has been brought into prominence by Prof. Brackett, of Princeton College, is evidently as nearly perfect as practice can realize, for with properly designed knife-edges and careful balancing, the arrangement possesses all the accurate qualities of the steelyard, and must be regarded as the very basis of power measurement.

In the case of the apparatus at the Stevens Institute, a dynamo weighing 3,000 lbs. was so balanced that a weight of 3 oz. (.1875 lb.) at ten inches from the spindle would cause the beam to vibrate through one inch at the index. When it is added that the absorbent of the power was a dynamo running through a rheostat adjustable in its resistance to the one hundredth of a horse-power, and as steady as possible, it becomes apparent that the test conditions are as crucial as a dynamometer can be placed under.

Three tests were made, two with a 200 incandescent light dynamo, and one with a 24 arc-light machine.

In the first case, the current from the dynamo was varied miscellaneously, by the fluctuation of resistance due to the switching in and out of lamps, etc.

In the second case, frequent and considerable alterations of current were made by the rheostat in order to show the degree of promptness with which the autographic instrument would respond to sudden changes of power.

Diagrams 1 and 2 show the resulting autographic records in the first case, and diagram No. 3 the records of the second case. The full lines of these diagrams are fac-similes of the actual pencil trace; the vibration of the pencil, usually so inseparable from the automatic registration of power, having been overcome by using a flexible brass wire *T* for a tracer. The point of the wire pressed upon chemical paper with sufficient friction to cause the vibrations to expend themselves in the flexure of the wire without displacing the point, while permanent movements of the wire were immediately responded to by a movement of the tracing point.

In the diagrams the crosses and broken lines are plotted observations from the Brackett dynamometer.

RAILROAD BUILDING IN MEXICO.

By Laurence Bradford, Member of the Boston Society of Civil Engineers.

[Read June 17, 1885.]

In treating this subject, I shall consider only peculiarities either of construction or locality, not found to my knowledge within the United States, and especially with reference to the Mexican Central Railroad, known outside the State as the Boston road; and it may be said the only one of many like enterprises in Mexico that fulfilled its obligations continuously and throughout. It mattered not whether their stock stood high or low, they never slackened their exertions until the City of Mexico was connected with our border line.

I will first speak of the face of the country over which the road passes, something entirely different from that of the Eastern States here, or any part of the West known to me. I may appear a little trite in some of the statements I make in this connection, but this perhaps would be thought more excusable than that I should make my meaning obscure.

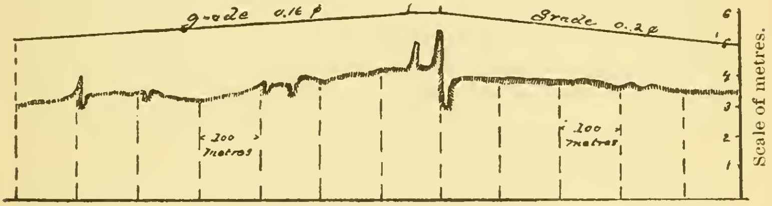
It is well known that the greater part of Mexico is table-land, but this must not be taken to mean that the surface of the country is level, or

comparatively so even, unless we regard it in one particular way—as a whole. If we regard it in this way, it will be found that the ground does not gradually slope for long distances, but is constantly up and down, with the average, perhaps, nearly level. Ranges of mountains on either side can always be seen from any part of the plateau; besides, ranges of smaller heights are constantly met with, which could hardly be called mountains. To the tourist or observer it would not be known that the ground did not rise or fall greatly in long distances, excepting as he noticed that there were no large rivers. One could hardly do as Humboldt said, ride in a buggy from Mexico City to the northern border line, across the country, disregarding the roads, though the figure of speech well illustrates the openness of a country where fences do not exist and where the streams are fordable. These ranges of hills and mountains that cut across the plateau make it, perhaps, as expensive a locality to build roads in as our own country. They do not there follow up the streams to obtain easy grades and light cuttings, or seek where the rivers head for passes across the water-sheds, but the surface of a plateau so much broken necessitates choppy grades and sharp curvature. The country is open and nearly devoid of timber, which lessens the expense of construction in one way, as clearing is avoided, but this is more than made up by the extra cost of railroad ties and fuel.

The material excavated is mostly *tepetate*, a volcanic substance lying beneath the soil, and varying in hardness from something like soft rock to clay. Rock is quite plentiful, though there was but little on the section where I worked. The streams are devoid of water in the dry season, even the largest of them; but in the rainy season, during the continuance of a storm, they become torrents. The rainy season lasts from about May to November, and though the rain-fall is light, about 26 inches, water does not lie far below the surface. All about Leon shallow wells supply the irrigation for vegetables; and in the beds of streams water is found a foot or so below the surface.

I will now go into the details of construction. From what I have said about the surface of the country, it follows that in crossing the ridges there must belong thorough-cuts. The tepetate, when first worked down, will stand perpendicular for quite a length of time; so the custom was to carry down only the width of road-bed, and afterward take down the slopes. It was quite a mooted question of just how much slope it was best to allow this material. When dry, it would stand perpendicular probably forever. When wet, it assumed more the consistency of clay, becoming smooth and slippery. There was very little haul in the construction of the road. It was mostly waste and borrow, the reason for this being that the material was carried on to the embankments and out of the cuts almost entirely by hand, and land being in many places worthless, it did not pay to carry any longer distance than necessary. The men carried the material in bags and baskets, and, of course, would not carry a large quantity at once; but it was surprising how from day to day an embankment would seem to grow from these continual but small accretions. A few carts were brought into service to fill up the embankments, taking from the cuts the portions that formed the slopes.

The streams have often scarcely a beginning or an end; heading in the ridges or mountains, they pour quickly down into the plains, and are lost in the dry soil of the plateau; tapering at both ends in shape like an earthworm. One finds here frequently the bed of a stream higher than the adjacent banks, to use an Irish bull. One man said he always supposed that streams were only to be found in the lowest parts of the valley, but since coming to Mexico, he comprehended how ignorant he had been, and that it was just as natural to find them flowing on the tops of the hills. This circumstance is easily explained: the Mexican planters have to seek the water-ways for irrigation, and their wheat fields are near the margin of streams that the water may be pumped over them, or a dam placed so the water may naturally flood them; consequently, the banks have been from time to time raised to keep back more water, and the beds of the streams have gradually increased in elevation from the sediment brought down. This instance, which I have drawn out on profile, by no means an isolated one, is on a part of the



1,850 metres elevation line.
Large Sauceda, 3 Spans 9 Metres each.

road I located between the cities of Leon and Lagos. The large Sauceda is on a small summit, and the highest elevation for a number of kilometres on either side. The stream is crossed by an iron bridge of three spans, 9 metres each. It occurred to me that this stream must have had an artificial origin. If so, however, it must have been centuries back, for on its banks are large trees of slow-growing species, many of which long since passed beyond their prime and are now decaying. Further on the section of another stream is shown, called the small Sauceda, which appears in the more natural way. This was bridged by a single span of 10 metres. It will be noticed that the grade lines also make a summit at the large Sauceda. Had there been no stream here, and the summit as shown on profile, it is readily seen how the grade could have been lowered and an expensive embankment dispensed with.

Small Sauceda, 1 Span 10 Metres.

The masonry of the road is excellent, both in workmanship and style. Stone-work construction is one of the strong points of the Mexican mechanic, and brings out in strong relief a phase of character in which he greatly excels—an accurate eye, with good taste to guide it. They have in Mexico none of the detrimental effects of frost to contend against,

and lime stucco ornamentation will wear for years. Sometimes they cover the face and arch of the culvert with stucco, as well as the parapet and wing walls, and often only the cornices of the parapet and wing walls, which makes a neat appearance. The lime of Mexico is of superior quality, and has some hydraulic properties. The illustration shows a simple but large-sized culvert: another one of similar construction is shown in the illustration of the deep fill. The culverts throughout the road are usually built like these. They are rather larger than the uninitiated would consider necessary, for the reasons I have named. I saw no bridges of stone on the line of the railroad, but very handsome ones are to be met with on the highways. The superstructure of the bridges was contracted for and built either in the United States or in England. The rails were contracted for in England or on the European Continent.

The metric system was here used on the railroads—a fact that has furnished subject-matter for much writing and discussion, if not food for much thought. Its practical use upon these roads has caused some interest among Americans, because it is the only instance of its use by us in engineering practice. My views may not agree with many others; I know they will not with those of my co-laborer, Mr. Fred Brooks, who has labored so long and ably for the universal acceptance of the metric system. However, I give my opinions, the result of my experience, and they can be taken for what they may be considered to be worth. As to the introduction of the metric system as a whole, I have nothing to say. Taken altogether, its advantages may counterbalance its defects in any particular direction, for aught I know. After being in Mexico a few months, I wrote for the *Engineering News* a short account of the practice of the metric measure there; further experience made stronger the adverse impression then made. The writer of a series of articles in the same paper said in effect this: that he presumed that the difficulties that the engineers in Mexico found in the metric unit of measurement would be found to disappear on further use. I think I can speak for the most of the engineers there in saying that they found no difficulty in its use. It certainly makes no difference to me what the unit of measure is, so long as it can be defined; that is, a stick cut to its length. But it is to be hoped that any of us could be credited with sense enough to perceive the superiority of one unit over another after practicing with both. The trouble in Mexico was, not that the metre did not represent a foot, or multiple of it: but because of faults inherent in itself. There were inconveniences in regard to units of measure for which the metre could not be held to account. The Mexican national units and those prescribed for the railroads were different at that time. So in dealings with the Mexicans, we had to use ordinarily the vara, equal to about 32 inches, and for long distances the league, equal to about 2.65 miles; but the engineers on the road usually used the metre and its multiples for everything. We guessed, paced, and thought in metres. A few, it is true, could not get over the use of the foot, and had to laboriously translate the metric dimensions to the old measure; but they were rare. Certain practices were followed on the road, it must be acknowledged, which, if done away with, would have made the use of the metre much

easier ; but to do away with its chief objection, I do not believe possible. I will describe the Mexican practice in detail. The *chain*—which represents a station on railroad work, the main large unit for survey and construction, and to be preserved after the road is completed, that the original location may be reproduced and old land lines and boundaries retraced if required—was 25 metres long. A more awkward division could not well have been chosen, though its total length made a convenient distance between stations. But it can readily be seen that 25 distinct units, and these units each divided in some chains into four parts and others five, made as inconvenient a measure as could well be devised for the purpose where a purely decimal division was so much to be desired. The chain should have a length, abstractly considered, that will best fulfillthe conditions of a large unit for the road, on tangents, curves, and in construction : that which is best for open country and timber, and in all other ways, considering everything. Upon the proper choice of this distance much of the expense and efficiency of superintendence depends, not to mention convenience. This chain should be divided up into one hundred small units. That a hundred feet exactly fulfills these conditions, I do not pretend to maintain, but I do say that its length comes somewhere near to doing it. All would probably agree that one hundred and thirty feet, abstractly considered, would be too long, and sixty feet, considered in the same way, too short. The small unit should be of such length that it will make an easy fold for the chain, and a division that will sufficiently sub-divide the curvature on sharp curves. Could a chain be formed of 100 metres, the conditions would be mostly fulfilled, or of 10 metres ; but one would undoubtedly be considered too long and the other too short. It has been proposed by some one advocating the metric system for railroad work, to get over this blemish in a way that brings to mind the old adage, that a person can most quickly show his crude ideas on a subject by the kind of questions that he asks. I would add, and by the suggestions that he makes. The way is this : The chain being 20 metres in length, that only every other one should be numbered ; that is, instead of having the chains count stations one, two, three, etc., two chains should count station one ; four chains, station two, etc. In leveling operations, an advantage which the metre appears to have over the foot, is that the rod is only divided in four main units—a division that seems to lessen the liability to error over having twelve main units. It is also an undoubted advantage in the calculation of earth-work to have the unit represent a side of the cubic measure used ; but these benefits I think are overbalanced by an increase of work in ordinary leveling. I have taken for an example a gradual slope of ground from the backsight to the foresight, an operation with some variations that would be repeated an almost countless number of times. These foresights have been worked up into elevations for both feet and metres, from which I calculate that about 19 per cent. is saved in figuring when using the feet measures ; and it comes about by considering the tenth of a foot as sufficiently exact for ground heights, while the decimetre would hardly be sufficiently close if assumed in the same way. For other purposes, where it is considered convenient or necessary, we have as good

In Feet.			In Metres.		
1580.32 Ht. of Ins.			471.681 Ht. of Ins.		
B. S. 0.35	0.3	1580.0	B. S. 1.06	0.09	471.59
	1.4	78 9		0.42	71.26
	2.6	77.7		0.79	70.89
	3.7	76 6		1.12	70.56
	4.5	75.8		1.37	70.31
	5.8	74.5		1.77	69.91
	6 2	74.1		1.89	69.79
	7.1	73.2		2.16	69.52
	8.8	71.5		2.68	69.00
	9.9	70 4		3.02	68.66
	10.4	69.9		3.17	68.51
	11.3	69.0		3.44	68.24
	12 2	68.1		3.72	67.96
T. P.	12.23	1568 09	T. P.	3.727	467.954

a measure in the yard as the metre—an easy multiple of the foot: and the fact that engineers who are also architects readily adopt the decimal measure in the foot and tenth for their engineering, and the duodecimal in feet and inches for their architectural work, with the yard as common to either, proves their willingness to avail themselves of what is desirable in both.

[Mr. Bradford had with this paper three photographs; one of an excavation 18 metres deep, one of an embankment 20 metres high, and one of some culvert masonry; all illustrating work on the Mexican Central Railroad. These photographs, while of much interest in showing the railroad work in Mexico, could not well be reproduced, and not in any manner without considerable expense.—SECRETARY.]

LONG AND SHORT-STROKE ENGINES.

BY WM. H. BRYAN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read May 27, 1885.]

An article entitled "The Real Difference Between Long and Short-Stroke Engines," from the pen of Mr. Chas. A. Hague, which appeared in the March number of the *Millwright and Engineer*, discusses the merits of the two styles of engine at considerable length, the writer arguing in favor of the long-stroke engine. Certain statements there made seem open to criticism, and to reply to them, as well as to present the short-stroke side of the question, is the object of this contribution.

The question is not a new one. From the time when the first steam engine began its revolutions, there has been no end of discussion. On the Western rivers this subject is now one of great interest, as much so as any other question of machinery, and it is probable a series of competitive tests may soon be arranged. Many hold that we are as far as ever from a solution, but I am convinced that important steps have been taken in the proper direction. There are of course, isolated cases, where special and unalterable conditions determine the character of the engine, and where these conditions must be maintained, even at a sacrifice of efficiency in other respects. In the great majority of cases, however, it is possible, by means of properly devised transmitting mechanism, to

adapt either a long or a short-stroke engine to the work. The question then to be decided is, which of the two types is the better or more economical engine to purchase? To properly consider this question in all its bearings, it is necessary to rightly understand what constitutes engine-value. A good definition is the following: That engine is the best which maintains a horse-power for the least current expense per hour. This question of current expense involves a consideration, not only of the first cost of the engine and attachments, but also the interest on first cost, depreciation, value of space occupied, repairs, and the operating expenses of fuel, oil, etc., and engineer's and firemen's wages. Another item, too, should be considered: the loss due to varying speed under changes of load or steam pressure, due to a want of sensitiveness in the automatic governing devices. This affects both the quantity and the quality of the work, and instances may be cited where it has been a serious matter.

Having thus defined the question at issue, let us notice the characteristic peculiarities of typical long and short-stroke engines. For purposes of comparison, I have selected as types two of the most prominent engines now on the market. The long-stroke engines are those in which the ratio of the length of stroke to the diameter of cylinder is from 2½ and 3 to 1; the sbort-stroke engines are those in which that ratio is from 1—or even less—and 1½ to 1. We notice that the piston speed is practically the same, being from 500 to 600 feet per minute in each case. From the fact that the long stroke makes fewer revolutions per minute, it has come to be known also as "slow speed;" and the short stroke, on account of greater number of revolutions, as "high speed." But as the piston speed, which more nearly represents the wear of the principal parts, is the same, these terms are misnomers, or at best have but a relative meaning. The former is not slow, compared, for instance, with western river engines, running 10 to 20 turns per minute. Nor is the latter fast, compared with locomotive practice. As an example of regular Western service, Missouri Pacific engine No. 304, cylinders 19×22, drivers 62 inches diameter, when running forty miles per hour, makes 217 revolutions per minute, or nearly 800 feet piston speed. In fact, 1,000 feet piston speed is frequently reached, and we have long since ceased to regard this duty as in any way hazardous. And this is done under conditions far more exacting than are ever required of a stationary engine.

In the long-stroke engine, four valves are required; in the short stroke, one. These valves perform the four functions of admission, cut off, release, and compression. In the long-stroke engine, these four valves can—at the shop or by the engineer—be adjusted independently, as desired. This is an excellent feature if a good man is in charge, but a bad one in the hands of an incompetent person who attempts "improvements," as many a proprietor knows to his cost. Experience has shown that this claimed facility of adjustment, secured as it is, by additional wearing parts, brings with it an increased wear and tear, and a constant tendency to lost motion in itself, which necessitates frequent attention to these adjustments. That is to say, these adjustments are made necessary by peculiarities of construction of the device itself, which is making a virtue of necessity, indeed. In the long-stroke

engine but one feature—the point of cut off—is altered with varying load or steam pressure, the admission, release and compression remaining unchanged. In the short-stroke engine one valve varies not only the point of cut-off, but also the points of release and compression, which add largely to the smoothness and efficiency of operation. The amount of lead is the only constant feature, and even that may be made to vary with the rest, if desired. The valve is carefully and accurately set once for all by the builders, and the regulator takes care of the adjustments. To those familiar with this style of valve, the remark of Mr. Hague—that attempting to do so much with one valve results in spoiling three good things—can only be taken in a humorous sense. Each of the four valves of the long-stroke engine has its full quota of connecting mechanism, largely increasing the number of wearing parts and the liability to breakage and derangement.

The belt which usually drives the governor on long-stroke engines is also an acknowledged but unavoidable evil. Most builders provide a stop motion, to prevent the engines running away in case this belt should break. The governor is also a distinctive feature. On the typical long-stroke engine it stands midway between shaft and cylinder, and is driven by a belt from the main shaft. The speed is governed by altering points at which the drop cut-off is liberated. This falling and replacing of the drop-off mechanism is carried on by the expenditure of some work, which, in many cases, affects the accuracy of the movement in question. The drop cut-off being detached from the opening mechanism, and part of its action being entirely independent of it, has not that rigidity of connection and certainty of action under working conditions which is desirable, and which a direct connection provides. It has been called the "perhaps" cut-off. To do away with this element of uncertainty, the builders of the long-stroke engine in question—which Mr. Hague champions—have themselves brought out an engine similar to their standard one in every respect, except the cut-off, which is made direct and positive. This engine was on exhibition at the St. Louis Exposition last fall.

In the standard long-stroke engine the cut-off is caused by releasing gear, whose motion is due to an accelerating force, and which, as it occupies an appreciable interval of time, limits the speed of the engine. This style of cut-off is acknowledged to be impossible above certain speeds, 85 to 100 revolutions per minute. In order, therefore, to secure the piston speeds which experience has shown to be best, long stroke becomes not a matter of choice, but of absolute necessity.

No better evidence of this is necessary than the practice of the builders of the long-stroke engine in question themselves. On their list of standard sizes are two, 32×48 and 40×60, which come under the short stroke definition, and yet admit of proper piston speed while using the liberating style of valve gear. And if further proof of the advantages of short-stroke and high speed were needed from the same source, it might be mentioned that they are now erecting a 40×60 engine which is to run 110 revolutions per minute, or at a piston speed of 1,100 feet, an undertaking which far distances the practice of the most ardent advocate of

short stroke. The performance of this engine will be watched with interest.

The governor of the short-stroke engine is essentially different. It is of the class by which the valve operating eccentric is moved relatively to the shaft by centrifugally acting weights, which vary the length of valve travel. The whole affair is attached to the main shaft, where variations of speed are first felt, and consequently is ready to act immediately without the intervention of belts or other transmitting devices. It acts directly on the eccentric whence a single rod with sliding support connects it with the valve. The valve being balanced, no work is done in moving it, whether at early or late cut off. Being direct connected, it cannot fail to act. There is nothing in its construction to limit its speed, which leaves the builders free to choose such rotative speeds as give the best efficiency.

The reduced number of parts in the valve gear and governor of the short-stroke engine results in great simplicity and compactness. The immediate benefits of this are reduced friction, wear and tear and likelihood of breakage or derangement, as well as less attention and watchfulness required on the part of the engineer. On account of short stroke and high rotative speeds, the short-stroke engine requires less floor space. In crowded cities or on board steamers, where every square foot has its money value, this is a consideration of no small importance. In no case is it wise to occupy space unnecessarily. Short stroke also admits of a rigidity of frame impossible in a long-stroke engine. Experience has shown that close regulation of speed is best obtained by high rotative speeds. It is possible to hold the changes of speed within one or two per cent. for extreme changes of load and steam pressure. The fluctuations of speed in passing the centres are also less marked: in fact, the high-speed engine seems to have no dead centres.

As will be shown later, the weight of material in the short stroke engine is proportionately greater than the long stroke, and its quality superior, as is also the grade and amount of workmanship. The points just mentioned—namely, small space required, great simplicity, compactness and rigidity, close regulation of speed, great strength and solidity of construction—would surely prevent these engines from "going a-begging," as Mr. Hague fears, even if their first cost per horse-power were equal to or greater than that of the long-stroke engine.

This brings us to the question of relative costs. The writer on long stroke charges the short-stroke engine with being the lower priced, but actually dearer engine. The opposite is more nearly the case. Comparing the weights and prices of our typical engines, the following facts appear: 1st. Taking the relative lengths of stroke as a basis of comparison, the short-stroke engine is some 25 per cent. heavier, the diameters of cylinder being the same. 2d. The selling price *per pound*, which indicates the quality and the amount of labor and the grade of material employed, of the short-stroke engine is to that of the long-stroke, about as 100 to 56. This increase of weight per unit of length and the higher price per pound show that the short-stroke engine cannot be termed a cheap affair. Compared with the long-stroke, it costs far more to build. If, however, we consider the net first cost per horse-power, the

short-stroke can usually be sold at a lower price. This is due not to any cheapening of the product, as has just been shown, but to a better adaptation of means to ends—a more efficient distribution of material, as well as the best of material and plenty of skilled labor. These are points of progress which the engineer may note with pride.

The statement of Mr. Hague, that this item of large power for small first cost is not advanced in favor of the short-stroke engine can be readily disproved by reference to advertisements.

Next in order is the cost of operating, and as steam economy is the chief hobby of the article in question, let us take this up first, with the indicator diagram as a basis. It would be easy to select cards from these engines which would not show the true relative efficiency, but which, by scientific jugglery, might be made to show in favor of either engine. Without going further into details, we will give results already obtained from short-stroke engines. Prof. R. H. Thurston very carefully tested an engine at Providence, R. I., under regular service, and which had received no special preparation whatever. He reports the consumption of steam per indicated horse-power per hour, as figured from the diagram, as 21.3 lbs. Engineers in the employ of Thomas A. Edison reported as a result of carefully made tests. 19.4 on the same basis. These results compare closely with the best that can be produced for the long-stroke engine, and the alleged difference of $24\frac{1}{10}$ per cent. fades into insignificance. Even on this excessive claim Mr. Hague is able to figure out a saving of but $\$105\frac{56}{100}$ per year, based on maximum St. Louis prices of coal—$2 per ton. The difference in price between a 50 horse-power long and short-stroke engine, which is the size he bases his calculations upon, is something like $1,000. Money being worth seven per cent.—his own figure—it would require some fifteen years to get back this original extra outlay—a financial scheme the beauties of which it is doubtful whether manufacturers can be made to see.

Referring more particularly to the indicator diagram, we claim for the short-stroke engine :

First, That the admission line is prompt, and reaches the nearest possible approximation to boiler pressure.

Second, That the steam line shows that this closeness to boiler pressure is maintained uniformly to the point of cut-off.

Third, That the cut-off is sharp and complete.

Fourth, That the expansion line is the nearest approximation to the theoretical curve.

Fifth, That the release is so arranged as to always clear the cylinder of steam of above exhaust pressure, before the beginning of the return stroke.

Sixth, That the back pressure line is as close to atmospheric pressure as friction through the exhaust piping will permit.

Seventh, That the compression is that best suited for smoothness of motion and efficiency in the use of steam.

In the matter of altering not only the point of cut off, but also the points of release and compression with varying load and steam pressure, the short-stroke engine secures results which are utterly beyond the reach of the long-stroke.

So much for the theoretical performance; the practical remains next to be examined. It will be necessary to examine first the subjects of "clearance" and "cylinder condensation." Considered alone, clearance is prejudicial to good economy, inasmuch as it causes a higher terminal pressure for a given mean effective pressure, the former indicating the amount of steam used, and the latter the work done. In long-stroke engines, clearance is usually about three per cent. of the piston displacement; in short-stroke engines it is from seven to nine per cent. in extreme cases. The loss, however, ordinarily due to large clearance space is in the short-stroke engine more than balanced by a gain due to early closure of the exhaust, causing large compression. The exhaust steam thus trapped may be—and frequently is—compressed to boiler pressure. The waste spaces being thus filled with steam at or nearly boiler pressure, do not call for additional steam when the valve from the boiler is opened.

The economy thus due to compression is well known. George H. Barrus estimates that a non-condensing automatic cut-off engine under given conditions, compressing up to boiler pressure, makes a gain of not less than six per cent. over the same engine under similar conditions running without compression. True, a certain amount of work is done in compression, but it is immediately given back on the return stroke. The only remaining objection, then, to large compression is that as it involves work, it necessitates some sacrifice of the normal capacity of the cylinder; that is, a smaller cylinder would do the same useful work if there were no compression. An examination of the action of the valve of the short-stroke engine will show how this difficulty is met. As already noted, the amount of compression varies inversely as the load, being greatest when the work required of the engine is least. The loss of capacity due to compression is then of no importance. As load is added, compression and the accompanying economy decrease, but the loss is small until an overload is put upon the engine. But when overloaded, all engines, without regard to length of stroke, suffer a loss of efficiency.

The loss due to condensation of steam on the internal surfaces of the cylinder is now the most serious obstacle in the way of improved efficiency, and its importance has led to long study and many experiments looking to a remedy. Tables of standard engine performance from the best authorities give the actual consumption of water per horse-power per hour in non-steam jacketed cylinders as over 28 per cent. greater than the theoretical or that calculated from the indicator card, taken at one-fifth cut-off. This enormous loss is due wholly to internal condensation. To work steam economically, it must be worked quickly, especially when used expansively. After cut-off, when the supply of heat from the boiler has ceased, the most serious losses occur, and that engine which accomplishes expansion in the least time certainly does it with the minimum loss.

One of Mr. Hague's statements is surprising—that "it is an immutable law of nature that the faster an engine runs, the quicker it will wear out." True, for any given engine, but to apply such a law generally and without further qualification is to ignore intrinsic differences in construction and peculiar adaptation to such service. The designing of a high-speed engine even for severe and continuous duty

presents no greater difficulties to the engineer than does the designing of a railway bridge to carry a certain load. Wear is due to friction, the laws of which are well understood, and multiplicity of parts. That the designers of short-stroke engines understand and are governed by these laws, the record of their machines abundantly shows. The alleged greater amount of oil necessary on the short stroke for a given amount of work: the claimed necessity for closer attendance, as well as depreciation and cost of repairs and liability to derangement, are all dependent directly upon the amount of friction and the number of wearing parts which we have shown to be favorable to the short-stroke engine.

In view of these facts we deny the assertion that the long-stroke engine "is the best, most economical, either scientifically or practically, the cheapest to own, and the easiest to run and take care of." On account of less first cost, interest and depreciation; less space occupied, greater regularity of speed; less friction and liability to breakage; and at least equal fuel economy, the *total* economic advantages, we claim, are in favor of the short stroke engine. We deny that the long stroke engine will make a sufficient saving in operating expenses over the short stroke, to justify any greater first cost whatever.

In what direction does the general practice of the day tend? The locomotive engine is a case in point where short stroke has proved best. Nowhere are *all* the elements of economic efficiency of so much importance, as in the proportioning of the cylinders of marine engines. There the present standard type is extreme short stroke, and is the outcome of a slow process of evolution. A fair example is H. M. S. Nelson, whose cylinders are 60 inch high pressure, 104 inch low pressure, 42 inch stroke. Out of a list of sixteen vessels of standard proportions no one of them has a cylinder less in diameter than in length of stroke. In most of them the diameter of high pressure cylinder is much greater than the length of stroke.

The standard long stroke engine comes to us embodying long years of study and experiment, and as the first successful example of high efficiency of steam. It has been through hard service, been subjected to severe tests, and has accordingly come to be regarded as the ideal steam engine. For this as well as for its well-known superiority to ordinary types of engines, it is destined to many years of usefulness. Yet, the advancements of recent years will bear out the conviction that it must now share the honors with its latest rival, the short-stroke engine.

No more fitting conclusion could be selected than the following, taken from Mr. Hague's paper itself:

"As far as the efforts of high-speed engineers tend toward the production of good or better results for less outlay of capital, we may be set down as heartily commending them, because the social and commercial demands of the world are in this direction, and he who opposes a practicable advance will be most assuredly crushed, whether he knows the reason of it or not. The eternal fitness of things constitutes the supreme court of every-day practice, and from it there is no appeal."

It has been wisely said that he who causes two blades of grass to grow where but one grew before, is a human benefactor. May we not say with equal truth, that the artisan in iron and steel who causes to be done with one piece what formerly required many more, is a benefactor in the more prosaic world of force and matter.

PLANE OF REFERENCE FOR PRECISE LEVELING.

The Secretary of the Boston Society of Civil Engineers prints, by request, the following passages from Report of the U. S. Coast and Geodetic Survey for 1882 :

Extract from Appendix No. 9, on Field-Work of the Triangulation, by Richard D. Cutts, Assistant (p. 173) : "The spirit level is employed to determine the height, above mean tide, of the principal triangulation stations on the coast," etc.

Extract from Appendix No. 11, on Results of the Transcontinental Line of Goedetic Spirit-Leveling, by Charles A. Schott, Assistant (foot note on p. 518) : "A slight acquaintance with the laws of the tides indicates that the level of reference for spirit-leveling of precision can be no other than the average or so-called half-tide level of the ocean." * * * * "The spirit-leveling operations of the great trigonometrical survey of India, commenced in 1858, were started from the mean (average) sea-level of Karachi Harbor. (Tables of Heights in Sinde, the Punjab, etc., Calcutta, 1863). In the leveling connecting the Baltic with the Swiss levels the plane of reference is the mean water at Swinemunde, depending on fifty-four years of observations. (Leveling in connection with the measurement of arcs, by Dr. Seibt. Berlin, 1882.)"

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

MAY 20, 1885 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 8.05 P. M., twenty-four Members present, Vice-President L. Frederick Rice in the chair.

The record of the last meeting was read and approved.

The Government presented the following communication : At a meeting of the Government, held April 11, 1885, it was voted : That the matter of nominating a Committee on Weights and Measures be referred to the Society, with the request for more definite instruction as regards the scope of the work of the Committee.

On motion of Mr. E. W. Howe it was voted : That this communication be laid on the table until the next meeting.

A communication was read from the Civil Engineers' Club of Cleveland inviting this society to unite with other engineering societies in the consideration of the subject of the relation of Army and Civil Engineers in the Government service.

On motion of Mr. C. W. Folsom, the consideration of this subject was postponed until the next meeting.

Messrs. R. P. Coggeshall, M. T. Cook, A. S. Glover, Sidney Smith, F. P. Spalding, F. I. Winslow, J. Worcester, were proposed for membership, recommended respectively by D. Brackett and A. F. Noyes; D. Brackett and E. W. Howe ; F. P. Stearns and A. F. Noyes ; C. E. Clarke and F. P. Stearns; D. Brackett and H. Manley; D. Brackett and H. L. Eaton; J. R. Freeman and R. A. Hale.

Messrs. E. L. Brown, S. R Edmond and A. W. Hunking were elected members of the Society.

Mr. D. Brackett read a paper on The Distribution System of the Boston Water Works, and illustrated his paper with various drawings of pipes, special castings, etc., and exhibited and explained the Deacon and Church Waste Water Detectors.

[*Adjourned.*] H. L. EATON, Secretary.

JUNE 17, 1885.—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:35 P. M., seventeen Members present. In the absence of the President and Vice-President, Mr. C. W. Folsom was elected Chairman.

The record of the last meeting was read and approved.

The communication from the Government concerning the Committee on Weights and Measures was taken from the table, and on motion of Mr. Frederick Brooks it was voted : That the government be recommended to appoint Charles H. Swan, Charles W. Kettell and Thomas W. Davis a Committee on Weights and Measures.

The communication from the Civil Engineers' Club of Cleveland, the consideration of which was postponed for one month at the May meeting, was read, and on motion of Mr. Frederick Brooks it was voted : That the subject be referred to the Government with instruction to correspond with the committee of the Cleveland Club for the purpose of obtaining further information as to the probable line of action to be followed by the proposed committee, and report to the Society.

On motion it was voted : That the July and August meetings be omitted.

On motion of Mr. F. P. Stearns it was voted : That a vote of thanks be extended

to Messrs. W. W. Greenough, President, C. D. Lamson, Superintendent, and other officers of the Boston Gas-Light Company, to whom the Society is greatly indebted for courtesies received at its visit to the works of the company, June 17, 1885.

Mr. Frank W. Fuller read a paper on the Wellesley Water Works, and exhibited various plans, photographs, etc., illustrating his subject.

A paper on Railroad Building in Mexico, by Laurence Bradford, was read by the Secretary.

[*Adjourned.*] H. L. EATON, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JUNE 16, 1885 :—The 210th meeting was held in the Society's Hall at 4 P. M., President Williams in the chair.

The minutes of the preceding meeting were read and approved.

Upon ballot Mr. J. M. Howells and Prof. H. B. Herr were elected Members.

On motion of Mr. Wright, Messrs. Cregier and Artingstall were appointed a committee to draft memorial resolutions on the death of Mr. J. A. Porter, a Member of the Society.

The Secretary read letters from the Engineers' Club of St. Louis and the Civil Engineers' Club of Cleveland, asking appointment of a committee on the subject of the relations of army and civil engineers in the service of the general government.

Upon motion of Professor Cooley the following was adopted :

Resolved, That a committee of three be appointed to consider the present organization of the engineer service for the conduct of public works of the United States. Said committee to be empowered to confer with similar committees appointed by other engineer societies.

The President appointed as such committee Messrs. Cooley, Herr and Wright.

By request, the matter of enlarging the scope and operations of the American Society of Civil Engineers, as outlined in a personal communication from Mr. A. M. Wellington, was taken up for discussion. The expression of views of members present was unanimously favorable to the general suggestions made by Mr. Wellington.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

JULY 7, 1885.—The 211th meeting was held in the Society's hall, at 4 P. M. Mr. Cregier was called to the chair.

The minutes of the preceding meeting were read and approved.

The resignation of Mr. J. F. Aldrich, as a Member, was read and accepted.

The Secretary read a paper by Prof. J. A. L. Waddell, "An American Engineering Literature Society."

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

APRIL 14, 1885 :—Regular meeting held, President Halloway in the chair. The minutes of the last meeting were read and approved. Two volumes of the Annual Report of the Chief of Engineers of the United States (Parts II. and IV.) were received from the War Department. Also, from the Hon. M. A. Foran, the Report of the Director of the Mint for 1883.

The following report of the committee appointed January 13th was received and adopted :

To the President and Members of the Civil Engineers' Club of Cleveland :

GENTLEMEN : Your committee appointed to consider the question of the publication, in other technical ournals, of the papers read before the club, previous to

their appearing in the JOURNAL of the Association of Engineering Societies, would submit the following report:

Resolved, That it is the sense of the Club that all such papers should appear in the JOURNAL of the Associated Societies before appearing in other technical publications.

AMBROSE SWASEY,
JOHN WHITELAW, } Committee.
J. N. RICHARDSON,

The Chairman of the Committee on Annual Meeting reported a deficiency of $9.75, which, upon motion, the Treasurer was authorized to pay.

The following resolution by Mr. Leland was adopted:

Resolved, That the Corresponding Secretary be authorized to take active measures to procure photographs (cabinet where possible) of members who have been removed by death or otherwise, and to secure suitable frames for such pictures.

The following was adopted:

Resolved, That the President appoint a committee of five civil engineers to discuss and recommend a plan of action to the Club, regarding a memorial to Congress, asking that Civil Engineers be placed on an equal footing with Military Engineers in matters pertaining to public works, other than military. Amended by Professor Eisenmann, That at least three of the members of the committee be Civil Engineers who are now, or who have been, employed on United States engineering works.

The President appointed the following as the committee: Prof. J. Eisenmann, Chairman; W. P. Rice, J. J. Laman, W. T. Blunt, and James Ritchie.

Upon recommendation of the Committee on Membership, the following-named persons were elected Members of the Club, Mr. J. L. Culley acting as teller: Active Members—Wm. T. Blunt, James Ritchie, and Louis E. Chapin. Corresponding Member, J. B. Strawn; Associate Member, A. B. Richmond.

The President announced the standing committees for the ensuing year as follows:

Committee on Publication and Library—H. Paul, N. M. Anderson and M. E. Rawson.

Committee on Membership—John Whitelaw, J. N. Richardson and Ambrose Swasey.

Committee on Engineering and Surveying—Charles Paine, Chairman; W. P. Rice, Charles H. Strong, J. J. Laman and J. D. Varney.

Committee on Mechanical Engineering—S. T. Wellman, Alex. E. Brown, D. Appel, T. D. West and Walter Miller.

Committee on Railroad Engineering—C. M. Barber, C. W. Fenn, W. H. Searles, C. W. Paine and J. L. Sterling.

Committee on Architecture—F. A. Coburn, J. M. Blackburn, C. O. Arey, Theo. Rosenberg and J. T. Watterson.

Committee on Subjects Pertaining to Scientific Pursuits—W. R. Warner, J. Eisenmann, W. B. Wood, E. W. Morley and George Bartol. Each committee to select its own chairman.

W. P. Rice then read a paper entitled, "Wave Reaction," which was very generally discussed.

President Halloway read a sketch, giving an account of his visit to the New Orleans Exposition.

A vote of thanks was tendered to the gentlemen.

[*Adjourned*.] M. W. KINGSLEY, Rec. Sec'y.

MAY 12, 1885:—Club called to order by the President at 8:15 P. M. Twenty-four Members and one visitor were present. In the absence of the Recording Secretary the Corresponding Secretary was directed to keep the minutes.

The application of W. H. Bone was received from the Committee on Member-

ship, recommending him for active membership. He was duly elected an active Member.

An amendment was presented to change Article XIII., Sec. 4, of the By-Laws (second paragraph), to read as follows : The chairmen of these committees shall constitute the Committee on Programme, which committee, when formed, shall elect its chairman within one week after the committees are announced.

(Signed) S. J. Baker.
Harry B. Strong.
C. P. Leland.

The following resolutions were presented :

Resolved, That the President appoint a committee to consider the advisability of securing larger rooms for our meetings.

Resolved, That the President be requested to call occasional meetings for the informal presentation of matters relating to engineering experience, observation and inquiry, and for the further discussion of papers presented at previous meetings, such meetings to be informal and not to be meetings of record.

Resolved, That the presiding officer be requested to call a recess of from five to ten minutes' duration after the business of regular meetings is completed, and before the papers of the evening are read.

Resolved, That the Committee on Library and Publication and the Corresponding Secretary are authorized to prepare copies of the Constitution and By-Laws, and list of members of convenient pocket form.

Resolved, That the member of the Board of Managers of the Association of Engineering Societies is hereby requested to communicate to the Board the hearty approval of the Civil Engineers' Club of Cleveland, of the new and valuable eature introduced into the Journal in its Index Department, and the wish that it be continued ; also to communicate the thanks of the Club to Prof. J. B. Johnson, of St. Louis, to whom we are indebted for it.

Resolved, That the Recording Secretary be requested to enclose to new Members cards of introduction to the President, and ask that they be presented to the President during the recess at their first attendance.

Resolved, That the Corresponding Secretary transmit to the Hon. M. A. Foran and others who have presented papers and maps this evening the thanks of the Club.

Resolved, That the Secretary be instructed to have the map of New York Harbor mounted and placed upon the walls of the Club rooms.

Resolved, That the Corresponding Secretary be authorized to procure photographs of the three presidents of the Club, and place them on the walls of the room.

The resolutions were passed unanimously. An intermission of ten minutes was announced, after which Mr. C. P. Leland read an account of the life of John B. Jervis, and presented the Club with a handsome portrait of Mr. Jervis. Remarks were made by Mr. J. A. Sargent, Chas. Paine and Chas. Latimer.

The following resolution was introduced by Mr. Latimer, and unanimously adopted :

Resolved, That the thanks of this Club be extended to Mr. C. P. Leland for his donation of a fine, framed, steel portrait of the late John B. Jervis and for the interesting account of his life and services.

[*Adjourned.*] E. H. Jones, Corresponding Secretary,
Recording Secretary *pro tem.*

June 9, 1885 :—Regular meeting held, President Halloway in the chair. The minutes of the last meeting were read and approved.

Corresponding Secretary Jones reported that the following named persons had been selected by the members of the various committees to act as chairmen : Civil

Engineering, Walter P. Rice ; Railroad Engineering, William H. Searles ; Mechanical Engineering, T. D. West ; Architecture, Theo. Rosenberg ; Subjects Pertaining to Scientific Pursuits, N. B. Wood.

The following resolutions were adopted.

Resolved, That the committee and membership be requested to furnish to the committee having in charge the publication of the new list of Members, with Constitution and By-Laws, a revised list of the present membership of the club.

Resolved, That the Civil Engineers' Club of Cleveland, having learned of the projected establishment of the Cleveland Manual Training School, desires to express its approval of this method of educating and training young men, with a view of increasing the knowledge and interest in the mechanical arts and engineering.

After a short recess, the amendments to the By-Laws, as presented at the meeting of May 12, 1885, were adopted.

Mr. W. H. Searles then read an interesting paper entitled "Some Reminiscences of the Construction of the New York, West Shore & Buffalo Railway," for which he was tendered a hearty vote of thanks.

[*Adjourned.*] M. W. KINGSLEY, Rec. Sec'y.

Editors reprinting articles from this journal are requested to credit both the Journal *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. IV. August, 1885. No. 10.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

SOME TESTS OF THE STRENGTH OF MATERIALS.

By Prof. Wm. A. Pike, Member of the Engineers' Club of Minnesota.

[Read April, 1885.]

In this paper I propose to set before you some of the results of tests made in the testing laboratory of the University of Minnesota during the last three years.

I wish to acknowledge in the beginning my indebtedness to Mr. W. F. Carr, who has assisted me in working up the results, and to state that a large part of these tests have been made by engineering students of the University as a part of their regular work. The machine used was an Olsen screw machine of fifty thousand pounds capacity. In order to test full sized beams, such as are used in construction, we have devised an arrangement by which loads may be applied by means of a screw at the centre of a beam, and the reaction at one end weighed by the testing machine. In this case deflections are measured by means of a micrometer reading to thousandths of an inch, contact with a wire being determined by an electric current passing and causing a bell to ring.

The following classes of tests have been made, and will be taken up in their order as given below :

Tension tests of pine wood, compression tests of pine wood, transverse tests of pine wood, compression tests of bricks, compression tests of bricks with reference to position in kiln, transverse tests of bricks, crushing tests of stone.

Incidentally in these tests, in many cases, specific gravity and absorption of water have been obtained.

Tension Tests of White Pine.

The dimensions given in the first column in Table I. below are the least dimensions of the sticks, which were made of the sizes indicated for about a foot in the centre. These sticks had ends about fifteen inches long, which were enlarged so that they had shoulders about one and one-half inches square, which bore on the cross head and top platform of the machine, thus giving a shearing area of about forty-five square inches; in spite of which fact it was necessary to spike and clamp their ends in order to prevent splitting. From these shoulders, where the main body of the sticks was about one and one-half inches square, the sticks were tapered to the sizes given in the table.

TABLE I.—TENSION TESTS—WHITE PINE.

Dimensions in inches.	Load per square inch.	Specific gravity.	Modulus of elasticity.	Remarks.
1 × ½.........	7,110	.335 (?)	....	All these pieces were thoroughly well seasoned.
¾ × ¾.........	8,000	....	....	
½ × 1¾.........	7,882	.662	....	
1 × 1	10,000	.758	1,302,000	9 computations.
1 × ¾.........	6,000	.629	....	
¾ × ¾.........	10,240	.594	1,718,500	2 "
¾ × ¾.........	8,888	....	....	
1 × 1	9,500	.654	1,214,000	12 "
1¾ × 1	5,143	....	....	
1⅜ × 2½.........	7,854	...	....	
1 × $\frac{15}{16}$.........	10,485	....	1,493,000	7 "

81,102 ÷ 11 = 7,373 = average tensile strength.

An important fact determined from these experiments and not indicated in the table, is that the longitudinal shearing strength of white pine is even less than has been generally given, and it is hoped at an early day to be able to give definite figures as to such strength.

Compression Tests of Pine Wood.

There were thirty-five tests of white pine wood made, in which the dimensions varied from one inch cubes to pieces fifty-four inches long and three inches square, as shown in Tables II. and III.

These pieces were carefully watched and divided into two classes, those breaking by direct compression and those by bending. Table II. gives the results of those of the first class and Table III. of the second.

The fourth column of Table III. contains values of the constant a of the well-known formula for the strength of struts, found by substituting for f the average value of f in the twenty-three experiments where the pieces gave way by direct crushing. The value of this constant, as usually given for timber, is $\frac{1}{250}$, or .004, which it will be seen is very much in excess of any value here obtained.

It is not proposed to base a new value on these few experiments, but to give them for what they may be worth as indicating that $\frac{1}{250}$ is too large.

TABLE II.—WHITE PINE—COMPRESSION.

Dimensions in inches. L.	B.	H.	Load.	Stress.	Remarks.
1¾	1¾	1¾	18,700	6,106	Broke by crushing.
12	1¾	1¾	18,000	5,885	"
12	1$\frac{31}{32}$	1	10,900	5,533	"
1	1	1	7,800	7,800	"
54	3	3	47,000	5,222	"
36	2	4	35,010	4,376	"
48	2	4	49,000	6,125	"
24	2	4	36,000	4,500	"
24	2	2	14,500	3,625	"
2	2	2	25,100	6,275	"
2	2	3	29,000	4,833	"
3	3	3	48,900	5,433	"
2	2	4	46,400	5,800	"
1	2	1	11,600	5,800	"
2	1	2	11,000	5,500	"
12	2	2	18,444	4,611	"
12	2	3	27,615	4,602	"
12	2	4	42,493	5,312	"
12	3	3	49,525	5,505	"
24	3	3	45,346	5,038	"
24	2	3	16,100	2,683	"
18	1	2	9,500	4,750	"
12	1	1	6,200	6,200	"

121,514 ÷ 23 = 5,283 average

TABLE III.

PINE STRUTS—CROSS-BREAKING.

Dimensions in inches. L.	B.	H.	Load.	Actual Stress.	a in $P = \frac{f\,s}{1 + a\frac{L^2}{H^2}}$
24	$1\frac{31}{32}$	1	8,650	4,391	.00032
54	4	2	30,600	3,825	.00052
48	4	2	21,550	2,694	.00164
36	3	3	41,720	4,636	.00097
36	3	2	16,100	2,683	.0029
54	3	2	16,050	2,675	.00134
48	3	2	17,675	2,946	.00137
48	2	2	11,400	2,850	.00149
54	2	2	9,300	2,325	.00173
48	2	1	3,025	1,513	.00109
36	2	1	5,200	2,600	.0008
36	2	2	13,100	3,275	.00189

.01608 ÷ 12 = .00134, average.

Transverse Tests of White Pine.

These tests are separated into two classes, small and full sized, as shown in Tables IV. and V.

The *small* beams were all twenty inches in length, and were all of clear stuff without knots, while the large ones are just such pieces as are used in construction, and were up to the average of their respective sizes. The important point of these experiments is in the marked difference between the small and large pieces, showing the imperative need for tests on full-sized pieces, on which to base dimensions of structures.

TABLE IV.

PINE BEAMS—TRANSVERSE STRENGTH.

Dimensions in inches. L.	B.	D.	Centre load.	Stress.	Modulus of elasticity.	Specific gravity.
20	3.94	2	6,600	6,377	....	.46
20	2	3.94	4,930	9,384	....	.56
20	4	2	3,100	5,812	4,114,000 (8) *	...
20	2	2	1,710	6,412	877,116 (11) *	...
20	1½	1½	570	5,007	....	...
20	1	1	290	8,700	1,500,000	...
20	1	2	920	6,900	....	...
20	2	3	3,000	5,000	....	...
20	4	2	3,100	5,812	....	...
20	3	3	6,000	6,666	....	...
20	3	2	2,700	6,750	....	...

72,820 ÷ 11 = 6,620, average stress.

* Number of computations.

TABLE V.

PINE BEAMS—TRANSVERSE STRENGTH.

Dimensions in inches.* L.	B.	D.	Centre load.	Stress.	Modulus of elasticity.	Specific gravity.
11½	4	4	1,010	3,266	910,000	....
11½	6	3⅝	2,300	3,413	777,900 (17) †	.621
11	6	6	5,560	5,096	1,519,900 (29) †	.640
11½	5½	7¾	9,400	5,985	1,666,700 (31) †	.677
13	4	8	4,800	4,950	1,277,336 (14) †	.617
13	3⅞	8	3,275	3,486	1,263,426 (15) †	....
12	4	6	3,237	4,856	2,630,000 (12) †	....
12	6	8	8,300	4,669	1,464,000 (4) †	....
12	4	8	4,000	3,375	1,265,000	....
12	6	8	8,200	2,332	1,415,000	....
12	4	4	1,050	3,543	....	....

44,971 ÷ 11 = 4,088, average stress.

* L. in feet.
† Number of computations.

Compression Tests of Bricks.

Table VI. speaks for itself, as to kind of tests made, the only remarks necessary being that these tests were made generally on half-bricks, except in one or two cases, when half a brick was beyond the capacity of the machine, and that in all cases a piece of pasteboard about $\frac{1}{16}$ of an inch thick was placed above and below the brick to distribute the pressure.

Table VII. gives results when brick from different parts of same kiln were tested, showing perhaps a greater difference in strength than was supposed.

Table VIII. gives results of four transverse tests of bricks with supports seven inches apart, and loaded in the centre by means of a rounded knife-edge.

TABLE VI.—BRICK—COMPRESSION.

Kind.	Load per sq. inch.	Specific gravity.	Per cent. abs. water.	Remarks.
St. Louis (1)	6,494	2.44	$13\frac{3}{10}$	Flatwise.
" (2)	6,060	......	......	"
" (3)	7,143	2.44	......	"
" (4)	3,878	......	.....	"
" (5)	7,500	......	......	"
" (6)	7,427	......	......	"
	38,502 ÷ 6 = 6,417 average strength.			
St. Louis (1)	4,080	......	......	Edgewise.
Red brick—Hastings (1)	2,622	2.017	$2\frac{6}{10}$	Flatwise—hard.
" (2)	2,439	2,012	$4\frac{6}{10}$	" —medium.
" (3)	600	1.748	$6\frac{7}{10}$	" —soft.
Red brick—Anderson (1)	3,000	1.9	11	
Chicago (2)	3,143	......	......	
Perth Amboy	3,364	......	......	
	9,507 ÷ 3 = 3,169 average strength.			
St. Paul (1)	3,120	......	....	Baked hard.
" (2)	1,557	......	......	Lighter.
Menomonee, Wis. (pressed)	2,182	2.35	$14\frac{5}{10}$	
Menomonee, Wis.	4,440	2.24	9	
	6,622 ÷ 2 = 3,311 average strength.			
Enamel brick Union Depot) (1)	5,309	......	......	
" (2)	3,900	......	......	
	9,209 ÷ 2 = 4,605 average strength.			
Red—North Minneapolis	782	2.28	$18\frac{15}{100}$	
" "	684	2.30	......	
" " (pressed)	1,018	......	......	
Coon Creek (Anoka Co.)	4,767	1.95	$10\frac{8}{10}$	
Hobart and Porter (Indiana	1,560	1.75	$19\frac{8}{10}$	
" "	1,420			
	2,980 ÷ 2 = 1,490 average strength.			
Jordan, Scott Co. (pressed)	1,599	......	......	
" "	1,795	......	......	
	3,394 ÷ 2 = 1,697 average strength.			
New Lisbon (pressed)	6,823	2.50	$7\frac{2}{10}$	
"	2,285	2.50	8	Edgewise.
Red Wing	948	2.30	$10\frac{1}{10}$	
"	666	2.30	......	
	1,614 ÷ 2 = 807 average strength.			
Zanesville, Ohio (pressed)	3,250	2.41	$15\frac{1}{10}$	
" "	2,286	2.41	$15\frac{2}{10}$	
	5,536 ÷ 2 = 2,768			

Kansas City (pressed)	1,770	......	......	
Philadelphia (pressed) (1)	3,630	......	......	
" " (2)	3,630	......	......	
Wisconsin	1,680	......	. ....	On end—soft.
"	3,757	......	......	On end—hard.
Cream brick—				
Chaska (sand mold)	686	2.29	$33\frac{2}{10}$	
" slop	342	......	......	
" "	661	......	......	
"	3,074	......	......	
"	3,496	2.33	......	
"	3,496	2.33	......	
"	1,746	2.34	......	
" (sand mold)	2,743	2.38	$16\frac{7}{10}$	
Minneapolis (wire cut)	1,055	2.49	......	
"	1,000	2.49	......	
" (slop)	2,168	2.21	$17\frac{5}{10}$	
" "	1,957	2.29	$17\frac{5}{10}$	
Bismarck (pressed)	3,025	2.36	......	
" "	2,089	2.36	.. ..	On edge.
Clarissa (Hartford, Minn)	3,445	2.29	$21\frac{9}{10}$	

TABLE VII.

TESTED WITH REFERENCE TO POSITION IN KILN.

Kind.	Load per sq. inch.	Specific gravity.	Per cent. abs. water.	Remarks.
Little Falls, Minn. (1)	3,467	......	18	Arch brick.
Shingle Creek (2)	2,800	1.55	24	Next to arch.
Little Falls (3)	2,400	1.50	22	Next course above arch.
" (4)	2,000	1.56	26	⅛ from top toward arch.
" (5)	1,237	1.45	29	Next to casing.
" (6)	1,155	1.42	28	Centre of kiln.
" (7)	1,100	1.61	20	¼ from top toward arch.
" (8)	980	1.54	25	" " "

TABLE VIII.

BRICK—CONTINUED—CROSS-BREAKING.

Kind.	Load.	Stress.	Sp. gr.	Abs. water, per cent.	Remarks.
St. Louis (1)	1,320	685	2.44	$13\frac{3}{10}$	7″ between supports.
" (2)	1,150	594	2.44	....	" "
Enamel (Union Depot)	987	456	....	....	" "
Minneapolis wire cut	260	151.8	2.49	....	" "

Table IX. gives the crushing strength of a number of stones used in construction in Minnesota. A more extended investigation into the strength of Minnesota stones, in particular, is now under way.

TABLE IX.

STONE—CRUSHING.

Kind.	Load per square inch.	Remarks.
Kasota (pink)	5,900	On bed.
" (light) (?)	12,500	On bed—still held.
" same	8,500	On edge.
Sandstones—St. Croix	3,025	On bed.
"	1,300	On edge.
" Red—Bayfield, Wis.	1,919	On bed.
" "	3,693	On edge.
" Red—Fond du Lac, Minn.	3,921	On bed.
Superior, Wis. (1)	2,560	On bed—weak streak.
" (2)	5,755	On bed.
" Berea	6,500	On bed.
" Buena Vista	9,250	On bed.
Limestones—Trenton, L. S.	6,442	
Mankato (yellow)	5,725	On edge.
"	9,362	On bed.
Iowa—Stone City	3,720	On bed.
"	4,500	On bed.
Nininger—Hastings, Minn.	6,020	On bed.
Quartzite—Sioux Falls, Dak.	15,000	On bed.

HOUSE-TO-HOUSE INSPECTION TO PREVENT WATER WASTE.

By M. L. Holman, Member of the Engineers' Club of St. Louis.
[Read April 29, 1885.]

During the latter part of December, 1883, and the first part of January, 1884, the daily consumption of water by this city was so great that the pumping engines were unable to keep up with the demand. On the morning of January 7 there was no water in the reservoir above the outlet gates, the draft on the supply main being so strong that the water pumped by the engines did not reach the reservoir. Large areas of the city were left without a supply of water. This excessive demand was occasioned by the consumers allowing water to run to waste to prevent it from freezing in the service pipes.

About noon of January 7 the Mayor issued a proclamation notifying all parties supplied from the city pipe mains to at once stop wasting water. The Mayor also authorized the appointing of a force of inspectors to examine all premises and see that the proclamation was complied with. On the 8th of January I was directed to take immediate charge of the inspection thus set on foot. A short account of the work done and methods of inspection used may be of some interest to those engaged in similar undertakings.

At first the inspection was confined to the central part of the city, the inspectors being assigned to certain routes and examining all premises supplied from the city mains. When a waste of water was found, the proper parties were notified to have the waste stopped at once. In cases where the waste was large and due to broken fixtures, the water was shut off at the stop-box. The service pipes to houses in St. Louis are provided with stop-cocks outside of the building. These cocks are generally situated near the curb-line, and are protected by stop-boxes with covers at the surface of the pavement. The stop-cocks are about three feet below the surface. The shutting-off of the water at the stop-box often occasioned great inconvenience to parties supplied from the same service pipe, but who were not wasting water. All cases of waste were reported by the inspectors and examined on the following day, and if it was found that the waste had not been stopped, as ordered, the parties were again notified. A third inspection followed, and if the former notices were found to have been ignored, a third notice was served and emphasized by the immediate shutting off of the water supply. This last notice generally had the desired effect, especially so as it was often followed by a fine in the police court. In many localities a second inspection followed the first, about an hour later. A great many places found all right by the first inspector were reported for wasting water by the second inspector. This double inspection served as a check on the inspectors and also prevented in a measure the waste of water. After the first inspection many people thought that they were safe for that day, and would turn on the water, only to be reported by the second inspector. In a few cases the third inspector got around with a notice and shut off the water before the second inspector was out of sight. This was done only where the waste was large and the parties willfully allowed the water to run to waste. In addition to the day inspection, a force was

employed from 5 P. M. to 12 P. M. to patrol portions of the city and report places found wasting water. This inspection was discontinued after a short trial, as it was found that the places open for inspection at that time kept watch for the inspectors, and would shut off the water as soon as they came in sight and turn it on again as soon as they left the premises.

This general system was kept up until the 19th of January, and resulted in a saving of water to such an extent that the supply was ample in all parts of the city. The water began flowing into the reservoir on the evening of the 8th, and on the 13th there was a good pressure in the elevated districts.

As it was necessary at this time (January 19) to continue the inspection, I reorganized the force and began a more thorough and systematic plan of work. The inspectors were assigned to duty in four sections or gangs, each gang being in charge of a foreman. The inspectors were required to make full daily reports in writing to the foreman, who transmitted them with a summary of all work done during the day. The method of inspection was that known as house-to-house inspection; the inspectors going from house to house and carefully examining all places supplied with water from the city mains. The general condition of the plumbing was reported as well as the cases of water waste found.

The results of this inspection are best shown by the following table. The column giving notices served includes only the notices for defective plumbing for the months of January and February. For the month of March it includes all notices. During the month of March and the following days in April the inspection was under the immediate charge of the Assessor and Collector of Water Rates, as it was necessary that I should resume work on the Water Works Extension on the 1st of March. Many of the places inspected were supplied by hydrants situated in the yards, there being no plumbing work in the houses.

TABLE NO. 1.

FULL AND COMPLETE DAILY STATEMENTS OF THE OPERATIONS OF THE SPECIAL WATER WASTE DETECTIVE SERVICE.

Date.	Number of Inspectors.	Total number of Inspections	Leaks and Wastes.	Notices Served.	Repair'd.	Shut off.
January 8, 1881	32	1,500	308	....	....	....
" 9, "	36	1,500	300	54	....	54
" 10, "	38	1,500	123	82	11	71
" 11, "	26	1,500	129	66	27	39
" 12, "	32	1,500	102	48	21	27
" 14.	31	1,500	125	27	5	22
" 15, "	23	1,500	165	51	22	29
" 16, "	24	1,200	130	25	5	20
" 17. "	25	1,500	133	44	14	30
" 18, "	24	1,350	133	18	7	11
" 19, "	25	1,437	138	38	17	21
" 21, "	32	2,277	217	44	18	26
" 22, "	34	1,876	171	55	38	17
" 23, "	34	2,444	169	64	29	35
" 24, "	40	2,623	241	49	22	27
" 25, "	41	2,630	217	51	26	25
" 26, "	36	2,227	182	58	26	32
" 28, "	38	2 496	121	44	20	24
" 29, "	40	2,135	106	53	28	25
" 30, "	40	2,377	142	49	13	36
" 31, "	40	2,450	184	59	16	43
		39,531	3,536	979	365	614

TABLE NO. 2.

Date.	Number of Inspectors.	Total number of Inspections	Leaks and Wastes.	Notices Served.	Repair'd.	Shut off.
February 1, 1884	28	2,254	201	56	24	32
" 2, "	28	1,872	152	57	20	37
" 4, "	28	1,530	127	60	21	39
" 5, "	31	1,764	200	57	23	34
" 6, "	31	1,858	325	52	21	31
" 7, "	30	1,192	169	85	31	54
" 8, "	28	1,220	155	53	20	33
" 9, "	29	1,421	135	81	48	33
" 11, "	29	1,435	134	50	15	35
" 12, "	13	..	...	16	3	13
" 13, "	29	1,528	138	...	....	....
" 14, "	28	1,564	138	47	15	32
" 15, "	36	1,801	131	45	21	24
" 16, "	35	1,952	189	36	17	19
" 18, "	28	1,220	80	48	20	28
" 19, "	24	592	38	33	17	16
" 20, "	33	1,070	85	26	11	15
" 21, "	27	1,436	110	35	16	19
" 22, "	29	1,835	129	44	21	23
" 25, "	29	1,614	101	52	9	43
" 26, "	30	1,349	88	39	17	22
" 27, "	29	1,785	106	29	10	19
" 28, "	29	1,756	87	38	18	20
" 29, "	32	1,911	121	36	14	22
		35,859	3,139	1,075	432	643

The necessity for an inspection that should detect and check the large waste of water at night was so urgent that steps were taken to arrive at some method by which such an inspection could be made. The method decided upon was to inspect a building for waste by ascertaining if water was running through the stop cock which controlled the supply to the premises, and follow this up with an inspection by the day force to find, if possible, the cause, and then stop the waste, if any was found. A few preliminary experiments were made for the purpose of ascertaining what could be done in the way of inspection and what special instruments were needed. After a few trials, some of which were made with the Bell waterphone, I found that the ordinary iron key used for turning on and shutting off water at the stop-boxes was all that was needed. A small portion of the key rod was flattened out so that the ear could be pressed tightly against it. After some practice with this instrument a test was made for the purpose of determining the smallest steady running stream that could be detected. The pipe selected for the test was a five-eighths inch service that led directly from the street main, without other connections, to the faucet where the water was allowed to run into a receiving tank inside of the building. The key was put on the stop-cock outside of the building and the flow of water regulated by turning the stop-cock until the smallest stream that could be detected by the sound transmitted by the key was obtained. During this test the faucet inside of the building remained full open. The faucet terminated the service pipe, there being no pipe beyond it to act as a reservoir. The test was made during the busy part of the day when the noise made by passing teams interfered to a

considerable extent. The stop-cock was about four feet under the sidewalk and the key used about 6 feet 6 inches long, half inch diameter. The least flow detected was a little less than *five gallons per hour.*

A force of inspectors was organized for night inspection, a gang consisting of four men—two for opening and cleaning out boxes, one to keep notes of work done, hunt up house numbers, etc., and one to use the key. The time selected for inspection was from 0 to 4 (12 P. M. to 4 A. M.). The men started to open and clean out boxes, and were followed by the keymen, who began work by getting the fork of the key firmly on the T-head of the stop-cock, controlling the water supply to the premises to be inspected. The inspector then pressed his ear against the flat part of the key-rod. If water was running with some little force inside the building, the sound transmitted by the key was plain and distinct. In case no sound was heard by the inspector, the water was shut off from the building and then turned on slowly, the inspector keeping his ear to the key while turning it. If no sound was heard during this trial the house was reported all right. If there was a small leak or waste going on inside the building, it gradually drained the pipes while the water was turned off. The amount of pipe thus emptied depended, of course, on the position of the waste. When the stop-cock was opened slowly the water rushed through to fill up the empty pipe, and gave a strong sound for a short time. The manipulation was necessary to detect small wastes; from half a minute to a minute with the water shut off was generally sufficient. In a few cases where the occupants were inclined to be skeptical, I gave them the benefit of a longer shut-off, and duly reported them for wasting water. Some discretion was necessary in order not to collapse the hot water boilers when there was one in the house. With this method of handling, the ordinary iron key is preferable to the Bell waterphone, or any other similar device, and is much cheaper. If I remember correctly, the amount asked for the right to use the waterphone in this city was $75,000. Several cities did invest in this expensive method, when a little actual inspection work on the part of those in charge would have rendered the expenditure unnecessary.

A few reports are given to show the work done. The inspection was carried on in the western part of the city, where the boxes were in fair condition. Houses in which the use of water during the night was due to sickness are reported as all right.

NIGHT INSPECTION, JANUARY 31, 1884.

Number of houses inspected	94
Number of houses all right	62
Number of houses wasting water	32

The following inspection by the day gang of the 32 houses reported above showed:

12 houses with plumbing in good order and no waste.
20 houses with plumbing in bad order and water wasting.

NIGHT INSPECTION, FEBRUARY 1, 1884.

Number of houses inspected	75
Number of houses all right	49
Number of houses wasting water	26

The day gang reported on the 26 houses as follows:

17 houses all right.
9 houses plumbing out of order and water wasting.

On account of the small number of fixtures reported out of repair by

the regular inspectors, I began a more careful system of inspection. The following report will show the result:

NIGHT INSPECTION, FEBRUARY 22, 1884.

Houses inspected	191
Houses all right	131
Houses wasting water	60

The houses above were inspected on reports by night gang and reported all right by day gang previous to this inspection (Feb. 22); besides this, there had been two inspections by the regular day inspectors previous to the first night inspection. With the assistance of an inspector. I examined the 60 houses, and found 19 houses with plumbing in good order and no waste at time of day inspection, 10 houses where the fixtures were in good order, but the water was found running to waste, 30 houses where the fixtures were out of repair and water running to waste. The key was used during the day inspection to ascertain if water was running through the stop-cock after all of the fixtures in the house were closed. It took a very careful inspection to find the small leaks. In one case, after going over the house twice without finding the cause for the flow of water through the stop-cock, I discovered the leak under the floor of the basement water-closet. The closet had been abandoned, and the small room in which it was situated was used for storing fuel.

NIGHT INSPECTION, FEBRUARY 25, 1884:

Houses inspected	120
Houses all right	81
Houses wasting water	39

The day inspection showed:

14 houses all right.
5 houses plumbing in good order, water wasting.
20 houses plumbing out of repair and water wasting.

In order to arrive at the permanent good produced by inspection to prevent water waste, by house-to-house method combined with the night inspection, I selected a district, and found that out of a total of 118 houses inspected during the night 59 houses were all right and that 59 houses were wasting water. Previous to this inspection all of the houses in this district had been inspected twice by the regular day men and twice by the night gang, followed each time by the day inspection of cases reported for wasting.

In all cases in this district where the notice to repair fixtures or stop waste was not complied with (as stated in the beginning of this account), the water was shut off at the box. The 118 houses were selected from those reported by the previous night inspections.

The following table shows the average force and work done:

Average number of key men per night	2
" " " assistants	6.7
" " " houses inspected per night	145
" " " " all right	107
" " " " wasting water	38

The amount of water saved and general results accomplished are best shown by the following from the annual report of Thos. J. Whitman, Water Commissioner:

"If we average the day and night consumption for five years previous to 1884 and compare it with the consumption of February and March of 1884, we certainly will arrive at the minimum benefit that this inspection has accomplished.

TABLE SHOWING AVERAGE HOURLY CONSUMPTION IN U. S. GALLONS DURING THE MONTHS OF FEBRUARY AND MARCH, 1879, TO 1884, INCLUSIVE.

	1879.		1880.		1881.	
	Night.	Day.	Night.	Day.	Night.	Day.
February........	830,000	1,120,000	680,000	970,000	900,000	1,200,000
March	730,000	1,105,000	630,000	930,000	870,000	1,260,000
Av. of 2 months.	780,000	1,112,506	655,000	950,000	885,000	1,230,000
	1882.		**1883**		**1884.**	
	Night.	Day.	Night.	Day.	Night.	Day.
February	880,000	1,180,000	990,000	1,210,000	673,000	940,000
March............	830,000	1,190,000	820,000	1,120,000	525,000	960,000
Av. of 2 months.	850,000	1,185,000	905,000	1,165,000	599,000	950,000

NOTE.—The day hours are considered to be from 5 o'clock A. M. to 11 o'clock P. M., and the night hours from 11 o'clock P. M. to 5 o'clock A. M.

"The average night consumption of these two months for the five years from 1879 to 1333 was 817,000 gallons per hour. For the same months in 1884 the average night consumption was 599,000 gallons per hour. This gives a saving of 218,000 gallons per hour on the night consumption.

"The average consumption for the day hours for the months of February and March of the years 1879 to 1883, inclusive, was 1,128,500 gallons. These months of the year 1884 the consumption was 950,000 gallons. This is a saving of 178,500 gallons per hour, and the saving on both day and night consumption amounted to 4,121,000 gallons per twenty-four hours.

"There can be no doubt but that by the employment of these inspectors a large waste of water has been stopped. I doubt, however, if as good results can be expected to follow a continuous practice of this system. Indeed, I am more than ever convinced from my observations of the work done by this force, that the only permanent and economical method of controlling the delivery of water to consumers for other than business purposes is in operating under some law similar to the proposed ordinance sent to the Municipal Assembly by the Board of Public Improvements.

Although the saving of water was considerable by this system of inspection, yet during the two months that I had charge it became very onerous to the water-takers. I was bothered by a great many groundless reports against my inspectors, representing them guilty of gross misconduct, etc., etc. Mr. S. F. Burnet and myself did nearly all the key work, and I generally found several reports on my desk during the day, giving us a good overhauling. Some persons thought to defeat the inspection by filling the stop-boxes full of sand; others tried old shoes, hard coal well rammed down, etc.

I regard the night inspection system as a very good method of house-to-house inspection, as it puts only those who are found running water to waste at night to the inconvenience of a day inspection. The great drawback is that a *waste* of water cannot be proven unless found by a day gang of inspectors employed to follow up the night men, all sorts of

excuses being offered to account for the flow of water through the stop-cock during the night hours.

The vital point of any method of house-to-house inspection is that the inspection can only be made efficient by keeping a very expensive force of inspectors, and they must be backed up by complete legislation. That the benefits of the inspection are only temporary is, I think, fully shown by the detail reports given.

WHAT CIVILIZATION OWES THE ARCHITECT AND CIVIL ENGINEER.

By George R. Bramhall, Member of the Western Society of Engineers.
[Read December 16, 1884.]

Of all the skilled professions, it is safe to assert that those of the architect and civil engineer stand in the front rank among civilized nations ; not only for the wealth, convenience and comfort they have contributed to society, but as the representatives of the grandest conceptions. the boldest achievements, that have been bequeathed either the Old or the New World.

And these achievements are of a character well calculated to excite in the mind of every intelligent being the highest degree of wonder and amazement.

While statesmen and jurists have framed wise and humane laws ; the military defended them, maintained right, and put down rebellion ; astronomers and mathematicians measured planets, given the movements of worlds and laws of navigation ; theologians instructed in religion ; musicians, poets and painters entertained and delighted multitudes by their powers of melody, pictures and song : physicians showed the laws of health and aided longevity ; chemists explained the laws of combination and reaction, the mode of composition and process of decay ; none have left such stupendous and striking demonstrations of wealth, genius and grandeur as the architect and the civil engineer.

Denon, the great French traveler and architect, well says, in speaking of the ancient Assyrian and Egyptian architecture, that it appears like a dream or the work of giants ; and he fancied he saw on every stone the words "posterity and eternity." Should a peasant, he says, be drawn out from his mud cottage and placed before such edifices, would he not believe there existed a wide difference between himself and beings able to construct them ? And, without any idea of architecture, would he not say, "This is the work of a god ; a man would not dare to do it, nor inhabit it."

War and defense, coupled with that quality of man's nature which constitutes the principle of sociality and love of home that has been implanted in the heart of every race and type of the animal man, and is found to exist even in the lower animals and insects, indicate the primal necessity for the architect and engineer.

Man's love for his offspring, family and social relations called for shelter, and as he grew in intelligence the necessity forced itself upon his mind of providing a permanent place of abode and protection, not

only against the inclemencies of the seasons, but also against his own race and his more natural enemies, wild beasts.

If man is the resultant of the forces of nature, by a long process of evolution (which is highly improbable), he had his first instruction in the art of building from the bee, ant, beaver, otter, musk-rat and other animals.

This is not an unreasonable or unnatural conclusion, since he is first found dwelling in caves, hollow trees, tents and mud huts, which show no greater evidences of skill in their construction and arrangement for protection, comfort and convenience than those of the animals.

But *these* builders have made no progress in their mode of life, and we are forced to leave them in the same habitations they were found in five thousand years ago.

There seems to be conclusive evidence that man, although none the less an animal, was endowed by the Creator, at the beginning, with all the powers and faculties of reasoning we find him possessing to-day.

He has been traced, step by step, from the cave, tent, mud hut, log hut, and house of hewn logs, to the temples, churches and cathedrals which adorn Europe and Asia, and the magnificent public buildings, legislative halls, palatial mansions, beautiful villas and elegant homes of a free people, scattered all over these United States of North America, our own cherished land of progress.

The magnitude of the subject permits only a cursory view of the most notable ancient and modern achievements.

Those in the Old World commanding the greatest attention are the temples, cathedrals, churches and aqueducts, and the reclamation of the Netherlands, better known as Holland.

There appears to have been a long period after the animal man emerged from his caves, huts of mud and dwellings on piles (of which evidences are found in the lakes of Switzerland), before he is found in villages and cities, and very little is known of his progress in architecture.

The first account, after this long lapse of time, seems to be of the building of the Tower of Babel, in which, it is claimed, that miraculous event, the confusion of tongues, occurred; and the fabulous mention of the city of Babylon.

Some Eastern writers give the height of the Tower as twelve miles, while St. Jerome more moderately asserts it was only four. The geographer Strabo, who may be relied on, says it was six hundred and fifty feet, which is more in accordance with our modern ideas and reason.

It is supposed that the city of Babylon and the Temple of Belus afterward occupied this same site. For a long period the whole history of this marvelous city is enshrouded in such a cloud of mysticism that it is exceedingly difficult for travelers or writers to determine anything reliable concerning it. It was founded 2,000 years B. C., and rebuilt 1,200 before the Christian Era.

Nineveh, the splendid capital of the Assyrian Empire, was sixty miles in circuit, and surrounded by high walls.

The accounts of the few travelers who long ago visited Asia and Africa were ridiculed and treated as extravagant fictions; but during the last

century, and especially since the commencement of the present, the investigations of scientific men have verified these seemingly incredible narratives. Stupendous edifices remain to demonstrate the truth of these wonderful stories, while structures of surpassing magnificence astonish the traveler in Egypt, Hindostan and Persia. When or by whom these everlasting monuments of man's might were erected, the present inhabitants know not. Their antiquity dates back to a period shrouded in dark uncertainty, upon which authentic history throws no light. They are themselves the only, the mysterious, the indestructible records.

It is impossible to determine with certainty which of these three countries first brought architecture to the degree of excellence which these remains exhibit. Sir William Jones and other Orientalists contend for the superior antiquity of Hindostan, and assert that the East was not only the birthplace of art and science, but that they were there nurtured till they grew to manhood. While this may be true, there is also strong testimony on the side of Egypt. Here, it is supposed by some antiquaries, inventive genius in architecture arose, and thence spread through the civilized regions of the earth. Others trace it farther down the Nile, and consider Ethiopia the land from which light emanated.

The traveler in Egypt is filled with wonder and admiration at the number, size and magnificence of the structures still standing upon the banks of the mysterious Nile. They are of three distinct orders: pyramids, excavations and temples.

The famous pyramids, forty or more in number, of different sizes and of various materials, are scattered over a plain extending from Cairo about fifty miles along the Nile. Cheops, said to be five hundred feet high, is the largest structure in the world, or, in other words, the greatest mass of materials men have ever placed together to form a single building. A distinguished countryman says, "the oldest pyramid is yet the most perfect work of art, though it has stood more than three thousand years."

The temples, scattered in rich profusion on both sides of the Nile as far as the cataracts, are so numerous and interesting that it is exceedingly difficult to know which to select for description. The splendid work prepared by the savants who accompanied Napoleon's expedition gives a perfect representation of these wonderful remains of Egyptian architecture.

Hundred-gated Thebes, spreading her solemn ruins on both sides of the river, shows the oldest specimens of true Egyptian art. Professor Heeren attempts to prove that Luxor, one of these old edifices, was a palace or building for civil purposes, though the general plan resembles a temple. He gives, among other circumstances, evidence to the effect that the occupations and scenes of daily life are depicted upon the walls of some apartments.

Among these mighty ruins must be mentioned the obelisks or monoliths. The sacred figures and hieroglyphic characters, beautifully cut in the hard granite, have the sharp finish of yesterday. The very stone looks not discolored.

Although the temples and other edifices of the Egyptians were painted with rich, bright colors, the character of their architecture was grave

and sublime. "No people," says Champollion, "either ancient or modern, ever conceived the arts of architecture and sculpture on so sublime a scale as the ancient Egyptians. Their conceptions were those of men a hundred feet high."

The straight lines and angles, unbroken by a single curve, give to the outlines of their structures a heavy, massive appearance, and while there is a general resemblance in the plan of their edifices, there is infinite variety in detail.

They must have been a very numerous people and under severe despotism. Whether the despotism that could command such immense power was that of a cunning priesthood, or a long line of ambitious monarchs, is uncertain. Probably the former, as most of the remains are temples dedicated to the worship of their deities. It is said that the wily priests exacted the hard earnings and ceaseless toil of millions to support an absurd, a monstrous system of idolatry. To keep the people in awe and maintain their blind adoration, the temples of their idols must be imposing and magnificent. Thus what was at first a useful art, became the most expensive and, considering the objects to which it was devoted, the most useless.

Yet, to the historian and architect, these grand remains are not useless. for they contain the chiseled record of the manners, customs, arts, sciences, literature and religion of a portion of the human race which would otherwise have been buried in oblivion.

The ancient edifices of Hindostan resemble those of Egypt in form and general character, yet are sufficiently marked to produce a peculiar style. The stupendous and magnificent temples of the Hindoos, many of which were hewn out of perpendicular rocks, must have been constructed downward till the temple was finished, where the foundations remain immovably fixed—a part of the primitive rock.

"The first view of the desolate religious city of Ellora," remarks Mr. Erskine, "is grand and striking, but melancholy."

The number and magnificence of the subterranean temples, the endless diversity of sculpture, the highly wrought pillars, rich mythological designs, sacred shrines and colossal statues, astonish but distract the mind. No trace, he says, remains to tell us the hand by which they were designed, or the powerful nation by which they were completed. The empire, whose pride they must have been, has passed away and left no memorial behind.

The beautiful ruins of Persepolis, probably the summer palace of a monarch, which Alexander partly destroyed, afford a fine specimen of ancient Persian architecture. Le Brun, who spent three months in exploring them, conjectures that Darius and Xerxes were the builders. Others think Persepolis was built by Egyptian architects. That there was communication of architectural knowledge between the three countries possessing the most magnificent specimens of art, cannot be doubted. The Jews, or Israelites, appear not to have gained much celebrity as architects, if the representations of King Solomon's temple we so often see are truthful. A seeming want in design has been concealed by everything costly and dazzling in decoration. In addition to this, it is said that when Solomon was about to build the structure, the workmen of

his own kingdom were not sufficient for the task, and those of other nations were employed.

In China the earliest attempts in architecture and building were close imitations of tents, and to this day there has been no departure from the original design. The discovery of ruins in Central America, immense in extent and perfectly anomalous in style, excited throughout Europe and our own country the most extravagant expectations. Scientific men looked for revelations of a race older than the Assyrians or Babylonians, but there are not sufficient grounds for belief in the great antiquity ascribed to them. In Greece, the land of the sage and philosopher, architecture reached its sublimest height. It is claimed by some to be the base of all the arts, and the one which first announces a degree of civilization, taste and intelligence in a nation. Grecian architecture bears sufficient resemblance to the best specimens of the Egyptian to demonstrate that they had studied and improved upon that, and in their temples and public buildings their genius and art excelled that of all other nations. One of the most magnificent temples at Athens, dedicated to Jupiter Olympus, was built of the purest white marble. Art, in the zenith of her glory, could present no prouder shrine. Vitruvius says: "This structure is not spoken of with common praise. The excellency and sagacious contrivance have been approved in the assembly of the gods."

Among the Romans, the first efforts of architectural skill were employed upon walls of defense. The unadorned works, constructed during the early ages, were remarkable for solidity. They were built of large blocks of stone in the most substantial manner, thus proving the early ambition which projected, from its very infancy, the Eternal City, the capital of the world. It is said little can be granted the Romans as inventors, either in religion or architecture. They were simply imitators of the Greeks. Some claim the arch is a Roman invention, but arches have been discovered in ruins older than Rome itself. Splendid remains testify how successfully they employed principles acquired from the Greeks. These remains are public roads, aqueducts, temples, theatres, tombs, historical monuments and forums. The Pantheon, their most celebrated temple, was completed twenty-seven years B. C. It was allowed to remain by the Catholics, who gloried in its conversion to Christianity. Among churches, St. Peter's surpasses any, ancient or modern. Three centuries and a half this cathedral was building, while the cost is estimated at $49,728,000. The base of the dome is 200 feet above the surface of the ground, and rises with its lantern and cross 300 feet higher. This is the wonderful cupola planned by Michael Angelo, one of the boldest attempts of architectural skill. Considering the number of pontiffs who ordered, and architects who planned, it is certainly wonderful that the proportions were kept inviolate, even to the most minute ornament. Michael Angelo left it an unfinished monument of his gigantic power, and his towering genius seemed to watch over his successors until its completion. Nothing ever surpassed, in effect, the interior of this church when illuminated at Easter by a cross of lamps suspended from the centre of the dome. All travelers dwell with enthusiasm upon the glory of this scene. Second in

magnitude and grandeur is St. Paul's, of London, whose first stone was laid in 1675. Completed in 1710, it was commenced and finished by the same architect, Sir Christopher Wren. The Grecian orders of architecture are largely mingled in both churches. Numerous magnificent churches of great size, built from the seventh to the tenth century and later, are scattered over Europe; St. Sofia, of Constantinople; Peterborough Cathedral, of England, erected by the Normans; Rochester Cathedral during William the Conqueror's reign, and many others. Many bishops of this period are known to have been skillful architects.

The round towers scattered over Ireland are hobbies among writers. Peter Walsh, in 1664, says they were never known before the eighth century, and were built by the heathen Danes as watch towers. When the Danes were driven from the country, the Christian Irish used them as steeple-houses or belfries. These towers, nearly a hundred in number, are from 50 to 140 feet high.

A number of churches on the Rhine were constructed in the eighth century, and at Lorsch a building still exists which was part of a church consecrated in the presence of Charlemagne, in 774.

During the 12th century, Gothic architecture made its appearance, and was the prevailing style in churches through the greater part of Europe. Whatever its primitive elements, it was created in Northern Europe and was adapted to the wants of a more inclement sky. If the origins of the Gothic style were various, no less so are the opinions as to the nation to which the invention belongs. It has been ascribed to the Hindoos, Egyptians, Hebrews, Romans, Greeks, Saracens, French, English, Germans, Italians, Spaniards and Scotch.

The crusades in the 12th century drew the flower of European chivalry to the East, and vast numbers of ecclesiastics accompanied them. Since they were the repositories of art and science during that age, it is more than probable they brought home many novel inventions in architecture. There was also, at this period, a corporation of builders or free masons, consisting of Greeks, Italians, French, Germans and Flemish, who kept secret the principles of their art, and traveled from place to place for the purpose of building ecclesiastical edifices. They had undoubtedly seen the finest specimens in the East and would introduce whatever was suitable for Northern buildings, especially in ornamental parts. Some of the best Gothic architecture is found in England, Germany and France. Westminster Abbey has been called by an English divine "the miracle of the world."

Cologne Cathedral is admired by many, as the finest specimen of the Gothic in Europe. The richness of its decoration can scarcely be imagined.

Rheims boasts the most celebrated cathedral in France, on account of its historical associations, immense size and antiquity. The kings of France were crowned in this church, which was founded more than a thousand years ago. Here it was that the unfortunate heroine, Joan of Arc, placed the crown upon the head of the ungrateful Charles. Some critics, however, consider Amiens Cathedral the perfection of Gothic architecture.

The Spanish cathedrals, though surpassingly rich, lack the grandeur of

those in Northern countries. Batalha, the glory of Portugal, was founded in 1385. The cathedral at Milan, a mountain of sculpture, has excited much admiration.

A popular traveler from our own country considers the famous Kremlin at Moscow one of the most extraordinary and beautiful objects ever beheld. It is two miles in extent, and is in itself a city.

Aside from temples and churches, there are multitudes of palaces and public buildings which attest the skill and genius of the architect.

And it will not be amiss to mention some of the noted buildings of our own country. Among these are the Capitol, President's House, Patent Office, General Post Office and Treasury Building at Washington; Girard College, United States Mint, United States Bank, Masonic Temple and City Hall, at Philadelphia; State House, King's Chapel and the Masonic Temple at Boston; Harvard College; Bunker Hill Monument; St. Paul's, Trinity, Grace Church, St. Patrick's Cathedral, Hall of Justice, in the Egyptian style, Merchants' Exchange, Herald Building, City Hall, Park Bank and Equitable Life Assurance Building at New York; the State House at Albany; the Washington Monument; the Catholic Cathedral and Merchants' Exchange of Baltimore; and the Custom-House, St. Charles Hotel, and Theatre of New Orleans. These, with the capitols of the different States and the public buildings of the Northern and Western cities, will compare favorably, and are not surpassed, by structures of like character in Europe. They are lasting monuments to architects of the Old as well as the New World. While some claim that architecture is the base of all the arts, it is unquestionably of civil engineering. This profession, though considered new by learned writers, was practiced among the Greeks six or seven hundred years before the birth of Christ, as is shown by their canals, channels and aqueducts for the conveyance of water. These were commonly structures of masonry to conduct water across a valley at a high level. Works of this kind are more properly called aqueduct bridges. It is necessary to bear this description in mind when dealing with the undertakings of the Greeks and Romans, for, since the former rarely if ever constructed aqueduct bridges it has been usual to institute very unfavorable comparisons between them and the Romans, who, with imperial disdain of obstacles, furnished the cities of their immense empire with a series of constructions of this kind which even in their ruins excite astonishment. True to the difference in national genius, the Greeks followed nature, and seeing the water collected in hills, passing for miles along subterranean courses, then issuing in cool fountains at the coast, adapted their system of conduits to the physical formation of the district; cutting tunnels and canals rather than bridging valleys, and, as a consequence, no conspicuous monument of their system remains. Although they accomplished so little that Strabo is justified in charging them with neglect, in comparison with the Romans, yet it is clear from the records that in this, as in other respects, they were the instructors of the Romans. The first Grecian aqueducts were constructed 625 years before Christ, and aqueducts, reservoirs and tunnels were common in Athens 560 years before the Christian era, some of which supply the city to this day, and are described as marvels of enter-

prise and skill. They are built of stone, some having pipes of baked clay within. The system of conduits in Syracuse, which the Athenians partly destroyed, still supplies the town with an abundance of drinkable water, and the point at which the tunnel passes under the sea to the Island of Ortygia, presents what is regarded as a remarkable achievement for early times.

At Tusculum is an example of early Italian constructions for the conveyance of water. An oblong basin is divided into channels which receive the water of a spring and distribute it by pipes. The basin is built of blocks of stone overlapping along the sides until they meet and form a roof—a principle afterwards supplanted by vaulting, and occurring in the earliest Greek masonry. If, to obtain a proper incline, the water-course had to be carried above ground, it was supported on a stone wall, and the conduit built of blocks of stone coated with stucco impervious to water.

Since a solid wall across a valley would cut off traffic, it was necessary to break it, by means of arches, into a series of pillars, and with this commenced the system of aqueduct bridges, which is the most striking monument of the Roman Empire.

Perhaps the best-known instance of this double purpose, an archway for traffic over which water can be conveyed, is Porta Maggiore, at Rome. The waters, taken over it in two separate channels, are Aqua Claudia and Anio Novus. From three inscriptions above the arches, it appears that the Emperor Claudius constructed the Aqua Claudia aqueduct from the springs Cacrutus and Curtius, forty-five miles from Rome; and the Anio Novus, from the sixty-second milestone from Rome; and that Vespasian and Titus restored them. Both aqueducts were commenced by Caligula thirty-eight years after the Christian era, and finished by Claudius ten years later. The length was sixty-two miles. Six miles from Rome the Anio Novus approached the Aqua Claudia, and from that point the waters traveled to the city in two channels, one above the other, supported by a chain of arches which at one place reached the height of 109 feet.

The Pont du Gard, as the aqueduct at Nismes is called, consists of three rows of arches striding across the valley of the Gardon. In the lowest row are six arches, one having a span of 75 feet and the others 60 feet each. In the second row are twelve arches, each with a span of 75 feet, while in the third are 36 smaller arches, and immediately above is the water-course. As a bridge, the Pont du Gard has no rival for lightness and boldness of design among Roman remains.

Twelve more aqueducts at Rome, besides those already mentioned, assist in the supply of water. A system of regular reservoirs along the course of the aqueducts, enabled repairs to be made at any point, and also let off water for the district they passed. A singular law decreed that material for repairs should be supplied from the private property nearest the damage; and what is still more strange, it was to be conveyed at the expense of the owner of the property. Public spirit or duty was at a high standard in those days; hardly as much could now be expected for the common weal.

Among aqueducts outside of Italy constructed by the Romans, and

still existing, the most remarkable, aside from the Pont du Gard, are those at Segovia and Tarragona in Spain. The former is 2,400 feet long, with 159 arches of greatly admired masonry in two tiers, reaching a height of 102 feet; and the latter 876 feet long and 83 feet high. At Mayence are the remains of an aqueduct 16,000 feet long, carried on from 500 to 600 pillars. Similar witnesses of Roman occupation can be seen in Africa and Greece. The aqueduct at Metz, which originally extended across the Moselle, here very broad, conveyed from Gorsa an abundance of excellent water. From a large reservoir at the source of the aqueduct, the water passed along subterranean channels, built of hewn stone, sufficiently spacious for a man to walk upright in. Similar channels received the water six miles from Metz, and conveyed it to the city. The bridge had only one row of arches, and the middle ones have given way, while the others are still perfectly sound. One of the principal bridges of the Antioch aqueducts is 700 feet long and at one point 200 feet high. The lower part consists almost entirely of solid wall; and the upper, of a series of arches with massive pillars. Both masonry and design are very rude. The water was drawn from several springs four or five miles from Antioch, and conducted by channels of hewn stone into a main channel of similar construction, and was carried across streams and valleys by means of arches. Many of these old remains now serve as highway bridges, notably that near Spoleto. It has ten arches, remarkable for elegance of design and airy lightness of proportion, each over 66 feet span and about 300 feet in height. The one at Pyrgos, now supplying Constantinople, called the crooked aqueduct, is composed of three rows of arches, is 670 feet long and 106 feet in the deepest part. It conveys the waters of the valley of Belgrade, one of the principal sources of supply. The other is the high ground west of the town, from which the water is conducted by similar conduits. The supply from all sources is 400,000 cubic feet per day. Egypt and Babylonia presented a different system of water supply. Since both countries were flat and traversed by great rivers, by which they were regularly inundated, canals with large basins took the place of aqueducts. The stupendous scale on which in Egypt the waters of the Nile, and in Babylonia those of the Tigris and Euphrates, were utilized, was a marvel to ancient travelers.

The most remarkable aqueducts in France are those built in the reign of Louis XIV., for conducting water from Marly to Versailles. The famous aqueduct bridge of Maintenon, for conveying the water of the Eure to Versailles, is without doubt, in magnitude and height, the most magnificent in the world. It is 4,400 feet in length, upward of 200 feet high, and contains 242 arcades, each divided into three rows, forming in all 726 arches about 50 feet span. The great works which supply Marseilles with the water of the Durance by a canal 60 miles in length, are among the boldest undertakings of modern times. This canal, completed in 1847, is conveyed through three chains of limestone mountains by 45 tunnels, forming an aggregate length of 8½ miles, and across numerous valleys by aqueducts, the largest, Roquefavor, surpassing in size the famous Pont du Gard. This immense volume of water, which passes at the rate of 198,000 cubic feet per minute, is carried across valleys by a channel of mason work, as in the old Roman aqueducts.

In British India, where the fall of rain is scanty and uncertain, artificial irrigation is resorted to. The Ganges canal, traversing the Northwestern Provinces of Bengal, distributes over this vast area nearly the whole volume of the Ganges. It begins where the river issues from the mountains, and 20 miles from its source crosses the valley of the Solani River; where the works for effecting the transit are designed on a scale of great magnitude.

Across the valley is an earthen embankment, raised on an average 17 feet. It has a width of 350 feet at the base, and 290 in the upper part. This forms the bed of the canal and is protected by banks 12 feet in depth and 30 feet wide at the top. To preserve the banks from the action of the water, lines of masonry, formed into steps, extend on each side the entire length.

The river is crossed by an aqueduct 920 feet long, having side walls 8 feet thick and 12 deep. In grandeur of design, solidity and utility, it challenges competition.

Croton Aqueduct. which supplies New York with water, is the only great work of this character in our country. At the time of its construction, it was justly regarded as one of the most magnificent works of modern times. Its length is 38¼ miles, and it is capable of discharging 60 million gallons per day. It is carried over the Harlem Valley in iron pipes laid upon a magnificent bridge 1,460 feet long, constructed of arches 114 feet above high water.

The water-works of Manchester and the aqueduct at Glasgow are in some respects the most stupendous ever constructed, and have attracted a great share of public attention. The most recent, and perhaps most complete in detail, are the Vienna water-works, and water supply of Paris.

The Vienna aqueduct is 56½ miles long. In order to reduce friction and facilitate the discharge, the inside is plastered with a two-inch coating of Portland cement and sand. This is in three layers, the last a very thin one of pure cement, which, when hardened, was rubbed with iron plates till perfectly smooth and polished. It was completed in 1873, and supplies twenty million gallons per day.

It is said that Nature is responsible for the planets, but man made Holland. Its history is a subversion of the laws of nature, and its successes illustrate what the science of the civil engineer can accomplish. Fifteen hundred and fifty miles of sea dykes, some forty feet high and broad enough for roadways, are now existing, the result of a constant engineering battle and incessant toil. Nearly the entire region is below sea-level, and the perpetual security can be appreciated when it is remembered that in 1277 a single inundation destroyed forty-four villages, while in 1287 eighty thousand persons were swept away, and its present shape given to the Zuyder Zee. Thousands of acres of fertile land have been recovered from the sea; 12,731 square miles between 1833 and 1877.

In our own country civil engineering has been of the same practical character as in Holland; adding in the largest degree to the prosperity and wealth of the nation.

While we cannot boast so many aqueducts as France or Italy, in num-

ber and size our railway bridges are unsurpassed. The age of railroads brought this branch of engineering to a degree of perfection hitherto unknown, especially in the construction of iron and steel bridges. Wooden ones date back to a very remote period. The first we have any account of was built in Rome 500 years B. C. The next was erected by Julius Cæsar for the passage of his army across the Rhine. Trajan's bridge, over the Danube, was made of timber, with stone piers. In the middle ages, when bridges were established as passages over rivers, they were usually constructed with piers, and were more notable for abundance of material than artistic skill. In this country the first wooden bridge of note is the one across the Portsmouth River of 250 feet span. Switzerland has several excellent wooden bridges. The most celebrated, that at Schaffhausen, built in 1757 by a village carpenter, was burned by the French after it had been in use 42 years.

The Romans built the first stone bridge. It was over the Tiber. Twice rebuilt the remains of the last structure are still visible. Pons Ælius had originally a roof of bronze supported by forty columns. Destroyed by the barbarians, it was restored by Clement IX., who placed on it colossal statues of angels carved in white marble.

In Egypt and India, the birthplace of so many arts and sciences, arched bridges were unknown; neither are they met in the ancient remains of Persia or Greece, though their architecture was the finest in the world.

The first stone bridge over the Thames, known as "old London bridge," was completed in 1209.

The novelty of Westminster bridge was the manner of laying the foundations. This was effected by means of caissons and inaugurated a new era in bridge architecture.

One of the most remarkable wooden bridges is at Havre de Grace It is 3,271 feet long and divided into twelve spans resting on granite piers. Constructed on Howe's plan, it combines great lightness with strength.

Washington Aqueduct bridge has some novel features. Its arches are of cast-iron pipes which carry the roadway and water supply at the same time. The bridge at Louisville, the truss bridge at Rock Island, the St. Louis Bridge and others on the Mississippi are noted both for design and strength.

Suspension bridges are of remote origin. Kirchen in his "China Illustrated" mentions one of chains supporting a roadway 330 feet in length, built A. D. 65. It is still to be seen.

The Peruvians constructed bridges over the Andes, the principal material being rope made from the bark of trees. Sometimes there were roadways, at others the transit was effected by a basket drawn alternately from side to side.

Iron suspension bridges, however, are of modern date. The first in England was built by Capt. Samuel Brown in 1819, across the Tweed. It was made with 12 chain cables, and the span was 449 feet. Several built in Scotland on the same plan, were destroyed by hurricanes.

Pesth suspension bridge was opened in 1849. The clear water-way is 1,250 feet, and the towers 200 feet from the foundations.

In the United States the first one was built between 1796 and 1810, of

chain cables. During the last 25 years wire cables have been universally adopted. Roebling's supension bridges at Niagara and Cincinnati are the finest of this type in tne country.

His bridge to connect New York City with Brooklyn is, without doubt, the grandest and most imposing structure in the world. It is 3,475 feet long, 135 feet high, and cost $15,000,000.

The cantilever bridge at Niagara has justly been pronounced a marvel in the science of bridge building. It is almost entirely of steel, and is 910 feet long.

Rush street bridge, at Chicago, Ill., designed by Mr. Samuel G. Artingstall, is the largest general traffic drawbridge in the world, the roadway accommodating four teams abreast. It is swung by steam power and lighted by electricity. For symmetrical proportions, completeness and elegance of design, it has no rival.

Tunnels are of very ancient origin, and were common in Rome several hundred years before the birth of Christ. 398 B. C., a tunnel 6,000 feet long, 6 feet high and 3½ wide, to tap Lake Albanus, was completed in one year.

When Cæsar arrived at Alexandria, he found the city almost hollow underneath from the aqueducts Every dwelling had its reservoir supplied by subterranean conduits from the Nile.

The aqueducts of the Romans, Peruvians and Mexicans included remarkable tunnels.

Among the celebrated tunnels of modern times are Mount Cenis, St, Gothard, Nochistongo, Sutro, Riquivel, Blaizy, Thames and Medway, and Chicago lake tunnel, which attracted much attention in Europe during its construction.

Canals are of still greater antiquity. The Assyrians and Egyptians built them first for irrigation, and afterward for navigation. They are now common in all civilized countries, notably in Holland.

Mr. Charles B. Stewart, Civil Engineer, in his "Lives and Works of Civil and Military Engineers," published in 1871, says that to the United States justly belongs the credit of building the longest canal in the world in the shortest time, for the least money and to the greatest public benefit. The Erie Canal, completed in 1825, is rightly claimed to have exerted an influence that beyond computation excels any investment of money ever made in any nation. Not only great States that border on the great lakes owe their prosperity, but the States beyond the great river Mississippi must forever find their markets through its channels to the Atlantic cities. Other and more rapid modes of transportation have diverted public attention from this pioneer improvement until few are aware that in the extent and value of its tonnage it far exceeds the whole foreign commerce of the United States.

In the remote and far East, many of the earliest and some of the greatest achievements of the architect are of a character to baffle the most learned antiquaries. They are unable to determine for what use or purpose many stupendous structures were created. Had not the library at Alexandria been destroyed, it would doubtless have thrown much light on problems that must forever remain a mystery. And the question is, has any benefit ever been derived from the construction of these

mighty edifices, whose ruins bear silent and solemn testimony of the untold millions which have been expended, and of cruel servitude exacted to gratify the ambition and vanity of kings and tyrants? A country may be richly adorned with temples, palaces, and hanging gardens which surpass even the Garden of Eden, and yet the masses be in the most abject and deplorable condition. To constitute real wealth and power, a country must possess other conditions. Among these are a just and liberal government, which is the foundation of a free and happy people, and great resources, both agricultural and mineral. These, with her manufactures, commerce, public highways, buildings, libraries and schools, make a nation truly great. Our own country possesses all these in an eminent degree. No nation, ancient or modern, ever made such gigantic strides in public improvements and works, as the United States in the last fifty years, and the civil engineer has performed a most conspicuous part in contributing to her wealth and power. There is no uncertainty, no question in regard to *his* achievements, which bespeak their real purpose to society from the very beginning. As evidence of the benefits bestowed upon society of modern times by engineering skill, it is only necessary to refer to the most noted, the railroads and ocean telegraphs. The first railroad in the United States, known as the Quincy, was constructed in 1826, and the Manchester and Liverpool road was completed about the same time. Up to 1882, Europe had 107,406 miles of railway and the United States 104,813, that of the former being about 2,600 miles in excess of this country. Illinois has the greatest number of miles of any State in the Union, and 504 more than the New England States and New Jersey combined. These roads, extending from East to West, span the continent, making it possible for one to travel from the Atlantic to the Pacific in a number of days that would have been months fifty years ago, and with a degree of ease and comfort inconceivable at that time.

Gigantic mountains, mighty rivers and deep valleys are no obstacles to travelers or traffic, since the skill of the civil engineer has divided continents by ship canals, tunneled the Alps, Hoosac, Alleghanies and Rocky Mountains; bridged the great rivers of the world and filled valleys: an apparent fulfillment of St. Luke's declaration eighteen hundred years ago, "That every valley shall be filled, and every mountain and hill shall be brought low: and the crooked shall be made straight: and the rough ways shall be made smooth." Could language be more prophetic or more in harmony with the achievements of the civil engineer in the nineteenth century. When civilization and its varied interests made it necessary to have daily and hourly communications between the Old and New World, the electric and naval engineer supplied the want by joining the two continents by a band of iron; the submarine telegraph, by which the great commercial and financial transactions of the two continents are largely maintained. Messages of love, sorrow and respect between friends, and the comity of nations, may be exchanged at pleasure and with the rapidity of the lightnings.

It has been said man made Holland; with equal force it can be stated the architect and civil engineer made Chicago, a city whose relationships, characteristics and rapid growth have no parallel in history. General

Watson Webb, lately deceased, in a recent letter to the Hon. John Wentworth, says that in 1822 there was neither house, hut, nor shanty of any kind, except those occupied by the employés of the government, other than those of John B. Beaubien and John Crafts. The first hotel was opened in 1826, when Chicago contained five houses. In 1830 the town was platted, and a year later the population numbered 75, and the cabin hotel gave place to a two-story building called the Sauganash. In 1833 Chicago attained the dignity of an incorporated village. The limits were made on the north to Ohio street, south to Jackson, and west to Jefferson, and it contained 550 inhabitants and 175 buildings before the close of the year, although there were only 29 voters at the time of organization. Chicago's first public loan, $60, was negotiated in 1834, and applied to making a ditch on each side of Clark street. In 1837 Chicago became a city, with an area of about 10 square miles, and a population of 4,100. The hydraulic company, designed to supply Chicago with water from the lake, was incorporated in 1848. In the same year the Galena Railroad was begun, which 'with the Illinois Central, commenced in 1851, was the introductory to that great system now represented by 18 trunk lines, which makes this city the greatest grain, lumber and provision mart in the world.

In 1857 the grade of the city was raised from 5 to 12 feet. One of the finest opera-houses in America was built in 1864 and the lake tunnel begun. The construction of our present system of water supply attracted much attention, not only in our own country, but also in Europe. This was due to the novelty of taking water down from a great lake for domestic and manufacturing purposes. Although tunnels had been constructed hundreds of years before the Christian era, this feature of engineering skill belongs entirely to Chicago and the nineteenth century. Millions have been expended in perfecting this grand system and in the erection of one of the largest pumping engines in the world, whose ponderous movements denote the power and purpose of the designer in supplying to this city one of the most essential elements to mankind with as great a degree of regularity in its pulsation as the human heart in supplying the life-giving current.

In 1871 the city area embraced nearly 36 square miles, and the population was 325,000.

On the 9th of October, 1871. one of the most destructive fires in the world's history occurred, burning over 2,124 acres and destroying 17,950 buildings, thus rendering 98,000 people homeless. Not only has this vast expanse of desolation and ruin entirely disappeared, but a new city has been virtually erected, which is not surpassed in its architectural beauty, number and magnificence of its public buildings and business blocks by any on the face of the globe.

Hon. De Witt C. Cregier, Commissioner of Public Works (our late worthy President,) says in his report to the Common Council in 1882, referring to official records of a petition bearing date August 13, 1835 :

"Your petitioner respectfully represents to your honorable body, that he has graded and thrown up La Salle street, between South Water and Lake, in front of lots one and two, and begs to be allowed the cost or value of said work, to be deducted from the taxes of the ensuing year.

"GURDON S. HUBBARD.

"To the Trustees of the town of Chicago."

He adds that the author of this is now a hale and active resident, who has witnessed Chicago grow from a frontier village to its present important place among the great cities of the world.

In his report for 1884 he has suggested public improvements, which, if carried out as outlined, will make Chicago the most wonderful city in the world, although less than half a century ago it was nothing but a swamp and quagmire, at seasons impassable to man or beast. Chicago in the future, as in the past, will be the theatre of the civil engineer, who has raised her from a marshy slough, paved her streets, constructed her labyrinth of sewers, erected great water-works and pumping engines, built splendid iron viaducts and drawbridges, one of which has been acknowledged the largest of its kind in the world, and supplied her with a network of street railways which, in detail, are the most complete in the system of street railways. With all these achievements, the city has but entered upon the threshold of her unsolved problems, which will require in their solution still greater power and skill in the engineer, and this hall will be a fitting place to discuss these questions and the plans for their execution. In all probability there are members of this society, and in all likelihood there are some now within sound of my voice, whose names will be enrolled with those of Geddes, Williams, Wright, Douglass, Latrobe and Roebling, in the future history of the profession and our country. In conclusion, does it not seem fitting to ask civilization to whom she is indebted for the great achievements which adorn the world; to which of the skilled professions is due the wealth, convenience and comfort enjoyed by all classes? Without one word of disparagement to any of the noble professions and arts which have contributed so largely to the power and progress of the present age, I repeat none have left such monuments of wealth, genius and grandeur as the architect and the civil engineer.

PUMPING MACHINERY VERSUS RESERVOIR.

By James Waters, Member of the Engineers' Club of Minnesota.

[Read May, 1885.]

The object of this paper is to point out some of the advantages that machinery has over reservoirs, where the water is elevated by artificial means, and has an inexhaustible source to draw from. It is not intended to substitute reserve machinery for the reservoir where the supply is limited at some seasons of the year, and it is necessary to have large storage capacity to tide over the dry time. At such places water must be procured at the proper season, and stored up for future use.

The advantages of machinery over reservoirs in the water supply of cities will be considered, first, as a reserve in case of accident; secondly, as to the ability to increase the pressure when required; thirdly, as to the economy of reserve machinery in first cost over the reservoir; fourthly, as to the quality of the water delivered by each system.

As a Reserve in Case of Accident.

It is a necessity of all water-works in this country that the water pressure in the mains should have an uninterrupted flow, day and night;

and as reservoirs and machinery both require repairing and overhauling, it is necessary to have a reserve in order that the repairs can be done without any inconvenience to the consumers or jeopardizing public property. The power to supply water in case of accident to the pumping machinery is the one great advantage claimed for the reservoir by its advocates, and is admitted, providing it is not being repaired itself or empty, as is often the case, from some other cause. To show its unreliability to meet the above requirements, I will relate an incident that happened at one of the best appointed water-works of that kind in the country. There were two pumps which could supply 10 million gallons each every twenty-four hours, pumping into a reservoir of 20 million gallons capacity. One of the pumps broke. The first thing to be considered, was whether the reservoir would hold out until the repairs could be made. The consumption was 14 million gallons per day, only ten of which could be supplied by the remaining pump. The other four million would have to be drawn from the reservoir, which at that rate would only furnish relief for five days. It was decided that the break could not be repaired in that length of time, so it was necessary to look to something beside the reservoir for help; which was obtained by purchasing additional machinery not quite enough to supply the full consumption; but by curtailing the use of the water they managed to get along at great inconvenience during the two hot months the break was being repaired. Since that time a third pump of 10 million capacity has been added to the supply, which, had this been done in the first place, instead of building the reservoir, would have afforded all the relief required.

The Power to Increase the Pressure Whenever it May be Necessary.

The reservoir being at one fixed elevation, the pressure cannot be increased unless the water in the reservoir is cut off by closing the gates in the supply main. And the chances are that, having a reservoir, so much reliance has been placed on it for an emergency, that a sufficient amount of pumping machinery has not been provided. All persons familiar with the running of water-works know that the size of the mains often becomes inadequate through the increase and spread of population, when extending out in long single lines in the suburbs of a growing city. But by being able to increase the pressure, the inconvenience can in a measure be done away with, and the time bridged over, until the district can be reinforced by additional mains. Also, higher buildings may be built, making it necessary to elevate the water accordingly. J. T. Fanning, in his report on a water supply for New York and other cities of the Hudson River valley, estimates that for that part of New York City below Central Park, the loss to water consumers from the lack of sufficient pressure is not less than a quarter million dollars annually.

The advantage of having the pressures for fires, without being at the expense of maintaining the water at that pressure except when necessary, is very great. The time it has taken to keep up fire pressure in Minneapolis has only averaged one hour in fifty-one this last year. When a system of water-works can give fire pressure on the mains, every hydrant is equal to a steamer. When that pressure is lacking, he

amount of water that can be thrown on a fire is limited to the capacity and number of fire engines a city possesses. Minneapolis and St. Paul are fair illustrations of the two systems. Minneapolis, by having adequate 'pumping machinery, can raise the pressure on the mains from about fifty pounds domestic to over 100 pounds for fire pressure. In St. Paul, the domestic pressure is about the same, with no means of increasing it in case of fire, and consequently all the water which can be thrown is limited to their six steamers; while Minneapolis, that has the same number, can supply her steamers with water, helping to increase their pressure at the same time; and in addition the pumping machinery could take care of six other fires requiring an equal amount of water, and that without any assistance from the fire engines. Although the water-works of the two cities are about of the same capacity, Minneapolis can furnish about seven times as much water for fire purposes. Another almost invaluable advantage is, that when the pressure is in the mains there is no time lost in getting up steam.

The assertion that the repeated increase of pressure in the pipes ultimately destroys them, is something that can only be determined after the lapse of ages. I know of a pipe 16 inches in diameter, and less than one inch thick—that has been in use over thirty years—during which time it has been subjected to variations of pressure ranging from 50 pounds to nothing, and from 130 pounds to nothing, frequently as often as 500 times in a minute. The increase of pressure in this city, in the pipes, on account of fires, would probably not average more than 365 times in one year, and then not as suddenly, or to the extremes of the pipe before mentioned. But allow them to have the same variations of pressure, they should not be destroyed from this cause in over a million years.

Economy of Reserve Machinery in First Cost over Reservoir.

Under this head I will refer again, as one example, to the city I have before mentioned. The reservoir at that place of 20 millions capacity, with its attachments, cost $250,000. The 10 million gallon reserve pump cost $65,000. So, if the pump had been procured in the first place, instead of building the reservoir, there would have been a saving of $185,000, and a much more efficient reserve. This proportion of reservoir and machinery at other places of course will vary, but the weight of the evidence is in favor of machinery.

Quality of the Water Delivered.

Machinery delivers the water to consumers before it has time to deteriorate. In all the reports received from other cities there is not one complaint against machinery on this point; but against the reservoir there are very many. There are various devices adopted to obtain from the reservoirs as palatable water as was pumped into them, one of which is to insert gates at different heights in the embankments, so that by drawing from different levels some stratum of water may be found less objectionable than the rest. Touching on this question, I will here quote from one of the reports: "During portions of July, August and September the water became strongly offensive—so much so that many citizens resorted to pumps and such well-water as could be obtained, and the commissioners were favored with a vast amount of advice as to what could be done to remedy the evil. Some urged that more vegeta-

tion be allowed to grow in the pond, others that fishing be permitted, while others thought that if the water could be skimmed and strained a perfect remedy would be effected. Then some were met with who thought the pond should be deepened on the shores and cleaned on the bottom from all impurities. On one point all agreed. That was that the water during this period was bad ; and on that point the commissioners fully agreed with them; but to cure the evil we must first find out the cause. Our city is not alone in this difficulty;" and then the report goes on to name many others troubled the same way. Quoting still further it says, "This subject has been investigated from a geological, botanical and zoölogical stand-point by the most accomplished savans in the country. This examination shows how widespread is the difficulty and how little hope there is for us at present, as the conditions under which we naturally expect aid have been experimented with and found substantially valueless." At this same city filtration was tried, proving of no use if the water was allowed to stagnate, and the only remedy was to turn it into the service pipes for immediate consumption.

In conclusion, I would say I hope this paper will be the means of provoking discussion on this subject, and thereby arriving at the most reliable and economical reserve for water-works—namely, machinery.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

JULY 21, 1885 :—The 212th meeting was held in the Society's Hall, at 4 P. M. Mr. Wright was called to the chair.

The minutes of the preceding meeting were read and approved.

Mr. Wright stated that in his paper on Ventilation of Stables, printed in Volume IV. of the JOURNAL, there was an error on page 194. In line 21 the amount of air, 392.4 feet, is that which each horse would get per hour if the area of ventilator was one square foot ; being 16 square feet, this amount should be multiplied by 16, the proper amount being 6278.4 feet. Mr. T. P. Perkins, of Lynn, Mass., first called Mr. Wright's attention to this unaccountable error.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

The quarters of the Society have recently been moved to the rooms of the Permanent Exhibit of Building Materials, No. 15 Washington street.

Members and their friends are specially invited to visit and examine this valu able exhibit.

AUGUST 4, 1884 :—The 213th meeting was held in the Society's Hall, at 4 P. M. President Williams in the chair.

The minutes of the preceding meeting were read and approved.

Professor Cooley, for the Committee on Organization of the Engineer Service for the Conduct of the Public Works of the United States, read a preliminary report.

It was voted that this report be printed, and that the other participating societies of the Association be requested to discuss the subject-matter ; and also that the report be taken up in this Society for discussion at the first meeting in October.

The Secretary read a paper by Mr. R. F. Hartford, on Ventilation of Buildings.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

REPORT OF COMMITTEE ON ORGANIZATION OF THE ENGINEER SERVICE OF THE UNITED STATES.

To the Western Society of Engineers:

Your Committee upon the Organization of the Engineer Service for the Conduct of the Public Works of the United States desires to submit a progress report as a basis for future discussion.

The facts, in brief, as they have presented themselves to our consideration, may be stated as follows :

(A) That the General Government has not yet formulated or defined a broad policy looking to a comprehensive scheme of public works of general utility to the nation ; nor has any duly constituted organization been provided for the study of such a system or for its practical execution when authorized.

(B) That appropriations have hitherto been made largely through local or sectional interests, that cannot appeal to the nation as a whole, and that their expenditure is assigned to the Secretary of War from time to time, as the appropriations are made, to be disbursed under his direction by officers of the army, detached from their regular service for this duty.

(C) That the employment of civilian engineers is in no way authorized or regu-

lated by statute, nor is their status, as servants of the Government, in any way defined.

In view of these facts, your Committee conclude as follows :

1. That if it is the policy of this Government to appropriate moneys for public works in the interests of commerce between the States, the improvement of harbors and rivers, and the development of new water routes on commercial lines, such policy should be formally adopted and carried out on a comprehensive plan, with due regard to topographical possibilities and commercial requirements, or the development of our waterways as a complete system.

2. That the inauguration and carrying forward of such a policy demands a comprehensive Bureau or Department of Public Works, charged with the development of a systematic scheme of works and its practical execution, said bureau to embrace all civil work of an engineering character, and to be organized solely with a view to its adequate development and prosecution.

3. That said bureau, in its organization, should recognize the natural division of our country into well-defined districts, with community of physical features and commercial interests, demanding related works, and also the relations of these districts as a whole.

4. That in the personnel of its organization, competence for the work in hand should alone be recognized, and that the organization should be such as will provide the best ability in every rank, founded on adequate training and experience, without regard to the mode or place by which due fitness may have been acquired.

5. Any organization that in its personnel and in its administrative duties is in any way influenced by partyism, or subject to political interference in the popular sense, would fail of a wise purpcse ; and if such freedom cannot be secured, the hope of an adequate system of public works may be indefinitely postponed.

Committee { L. E. COOLEY, H. B. HERR, A. W. WRIGHT.

ENGINEERS' CLUB OF MINNESOTA.

JUNE 12, 1885 : Regular monthly meeting. The President, Mr. George W. Cooley, extended an invitation to the Club to spend a day at his cottage at Minnetonka Beach, about the middle of July, which was accepted. Mr. D. P. Waters read a paper entitled "Cement and Silicate of Lime." Discussion followed.

[*Adjourned.*] W. A. PIKE, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.
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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

WATER-POWER AT NIAGARA FALLS.

BY SAMUEL McELROY, C. E., MEMBER AND V. P. WESTERN SOCIETY OF ENGINEERS.
[Read September 1, 1885.]

Under an act of April 30, 1883, of the New York Legislature, five commissioners were appointed to locate a public park at the village of Niagara Falls, which has been laid out to include the water front for about one mile above the Falls, Prospect Park at the Falls, with Bath, Luna, Goat and other islands on the American side.

Under this act three commissioners were appointed by the Supreme Court, to appraise the value of the lands and other property appropriated for this park, who commenced their sessions in February, 1884, and made a report October 27, awarding an aggregate sum of $1,443,439, provided for by a legislative act of April 30, 1885

The hydraulic power has been utilized by the hydraulic canal, Witmer's grist mill, the upper and lower races, and the paper mill on Bath Island ; below the Falls by Witmer's grist mill at the Suspension Bridge.

The hydraulic canal, about 4,000 feet long, runs from Port Day, a point just above the rapids, to a basin near the ledge on the American side, about half a mile below the fall. It varies in width from 36 to 74 feet, minimum depth about 7½ feet, and supplies 10 mills, using about 3,100 horse-power : a new flour mill is being built to use 1,000 horse-power additional. Advantage is taken of the ledge height by tunnels to obtain wheel heads of 50 to 90 feet, turbines being used. This is not included in the park.

The Witmer mill, on the river rapids, was built in 1800. It has four runs of stone, driven by three "Eagle" turbines, and one "tub" wheel, under a head of about six feet.

Two mill races were laid out near the falls, the "upper" and "lower," parallel with each other, fed by the rapids. The former is used for light hotel power ; the other has been long in use. Its original wing-wall was extended into the rapids in 1820–21. It furnishes power for two pumps, two carpenter shops, one cabinet and one machine shop, a large pulp-mill, and the dynamo engine and water-wheel of Prospect Park and its ferry railway.

On Bath Island, power is used from the rapids for a large paper mill, with two 54 and one 66-inch "American" turbines ; head 12 to 13 feet ; about 400 horse-power used. These powers were appropriated.

Lower Race Power.—In 1882 an action was commenced by an owner

on the lower race, Mrs. Townsend, to obtain a decree fixing the relative supply of water to the several lots, twelve in all on the race, and Prospect Park, claiming one lot, and a decree was rendered September 25, 1884, by Judge M. H. Peck, referee.

This case became an elaborate investigation of the conditions and value of water supply and power here, and furnished an important basis for the State case testimony, but the decree was not published when the appraisers concluded their awards, and is now the subject of an appeal to the Court of Appeals. Practically, the suit was an attempt to restrict the supply of the large pulp mill, which was the first to properly develop this race, the defendants being Messrs. Hill & Murray, its owners.

For the plaintiff Messrs. C. H. Rhodes and C. H. Pifer were counsel; Messrs. C. S. Olmsted, L. E. Nichols, Benj. Rhodes, civil engineers; Prof. I. F. Quimby, A. P. Burdick and J. Phillips, machinists, as experts. For defendants, G. J. Sicard, Esq., counsel: W. F. Noye, M. S. Otis, W. A. Philpot, millwrights and machinists, as experts. In the State case, where value of power became prominent, the witnesses for Hill and Murray were Clemens Herschel, C. E.; R. Rossiter, Supt. Paterson power; W. H. Nixon, paper manufacturer; D. T. Mills, turbine builder; Messrs. Noye and Otis, several machinists, and Samuel McElroy, C. E., consulting expert, in both cases.

The several points presented may be thus stated:

Relative value of water-power depends on the quantity, head, and regularity of supply, and its purity; on facilities for receipt and delivery of supplies and productions, and for labor and repairs; on the perfection of mill and machinery, and operation; quantity legally controlled; local conditions, and standards of similar power.

Quantity of supply: Source, Lake Erie; distance by river, 22 miles; time of river flow, 6 hours; flow of river, about 18,000,000 cubic feet per minute; power of whole Falls, at 150 feet, 3,600,000 horse-power on shaft; area of lake, 9,600 square miles; fluctuating range, about 1.8 feet; prevalent winds, W. and S.W., tending to keep up levels for about 70 per cent. of annual gales; flow uniform, day and night.

Race obstruction, by sludge ice, not to exceed a week in winter; cost to clear, about $350; winds produce occasional changes up to 1.5 feet; tail races rise and fall with inlet; virtual fall not impaired.

As compared with other powers, the Merrimack at Lawrence, draining 4,453 square miles, fluctuates from about 2,600 cubic feet per second in September to 18,000 in May; the general variation of head at Lowell is 5 feet on the upper fall of 32, and a reduction of 6 feet is sometimes caused by floods; the best head, where dams are used) from flood rise on the tail races), being in dry weather, if the supply does not fail. The Connecticut, at Holyoke, varies from 36,000 cubic feet to less than 2,500 per second; the Housatonic, at Kent, from 887 cubic feet per second in May to 263 feet in August; the Mohawk, at Cohoes, draining 2,830 square miles, runs down to 980 cubic feet per second, mill supply, in the dry season; the Genesee Falls are often dry at Rochester. Water wheels are subject to serious ice obstructions in winter; and few mills can be run, day and night continuously, summer and winter, as on this race.

Relative levels above mean ocean level: Lake Erie, 575* feet; Gill Creek, mouth, 566; Port Day, 564; Upper Race Inlet, 560; Lower, 542; Top American Fall, 515; Bottom, 350; Lewiston, 248.5; Lake Ontario, 246.5. Rapids fall about 46 feet in three-quarters of a mile.

Purity of water supply may affect the durability of turbines by comparative wear, and does seriously effect the value of certain productions, like paper pulp. The race supply differs essentially from that of Bath Island in this respect, and the pulp commands a better market. The depurative effect of Lake Erie on mechanical and organic impurities is important.

Freight facilities: With seven trunk railways, West, South and East, and with river, canal and lake navigation, direct access is had to the best supplies of timber at the lowest cost, and sharp competition exists for receipt and delivery of mill supplies and productions. Railway rates for pulp per 100 pounds to New York, 13 cents; Boston, 18 cents; St. Louis, 15 cents; Chicago, 13 cents; Wilmington, 15 cents; pulp from Paterson to New York, 17 miles, 9 cents; paper, Philadelphia to New York, 90 miles, 17 cents; rates from Holyoke much higher than Niagara. Labor and repairs, for the same reason, can be promptly and cheaply had.

Mill and machinery are of the best type. Mill of stone work on rock foundations; steel shafting; one 13, one 54, one 66 inch "American" centre vent wheels of the best pattern; Otis patent pulp grinders of high efficiency; electric lights; machines of the best pattern, operated day and night, except Sundays.

Inlet, formed by a wing-wall built into the rapids, which fall 18.44 feet in 0.224 mile, above it, and enter with chutes of 17 to 20 feet per second velocity; length about 360 feet, width about 50 feet, ordinary flow about 72,000 cubic feet per minute; waste, 30,000 to 37,200 cubic feet; capacity easily increased by deepening the entrance.

Race: Supplied from inlet by 9 gates, 6 of 4 feet by 4½, 3 of 4 feet by 5, seldom fully open; length, about 645 feet; width, 30 to 25 feet; depth, about 7½ feet; usual current, 1½ feet per second; ordinary use for power, 31,000 to 41,000 cubic feet per minute; waste, 3,800 cubic feet; capacity easily increased. Use of power: Lot 2, 5½ feet head, 5¼ horse-power: No. 4, 8 feet, 12 horse-power; No. 6, 8½ feet, 18 horse-power; No. 8, 12 feet, 12 horse-power; No. 10, 9 feet, 30 horse-power; No. 12, 9 feet, 10 horse-power; No. 16, 17½ feet, 425 horse-power; Prospect Park, 12 feet, 25 horse-power; wheels, except on No. 16, of low duty, of "Tub," "Flutter," "Smith" and other patterns, from 20 to 30 per cent. duty. Loss of head, inlets to pulp mill forebay, inlet, 0.20 foot; gates, 0.25 foot; arches and race, 0.55 foot; total, 1 foot.

Quantity controlled: Under the grant of January 30, 1840, each lot on this race was entitled to "so much water as will be sufficient by a prudent use thereof, to drive two runs, or pairs of mill-stones, upon such water-saving principles as are usually adopted by skillful engineers and builders."

The proper interpretation of this grant was the key to the contest

* A bench discrepancy at Albany, between the Coast Survey and United States Engineers, leaves this level in doubt; other checks make it nearly as given.

before the Referee, and on the supply and power required for a "run of stone" in 1840, the following testimony was presented :

Run of stone : The "shaft" power required for grinding, depends on careful adaptation of their structure, forms, weight and bearings to the work ; diameter, or rubbing surfaces ; sharpness, or "dress" ; durability of surface ; coarseness or fineness of "set" ; speed ; weight, hard and tough or soft texture, moisture or dryness of grain, and fineness of flour produced. The power for mill machinery in elevating, separating, bolting, cleaning, or regrinding the grain and its products, is additional, and varies with relative perfection of design and workmanship, and amount of work required.

Similar pairs of buhr stones may differ at times 33 per cent. in duty (Emerson Hyd., p. 297); former 5 and 6 feet diameters are reduced to 4½ or less, to reduce friction ; neglect of dress may reduce 11⅓ bushels per hour to 5⅝ (D'Aubuisson Hyd., p. 450). One run in five or six is generally idle for dressing ; 16⅓ to 20 per cent. more power required on runs at work ; old speed of 90 to 100 revolutions, or high speed of 175, modified to 150, for 10 bushels per hour. Weight per bushel : Wheat 60 pounds, flour 40 ; corn 56 pounds, meal 55 ; rye 56 pounds, flour 22½ ; oats 31 pounds, meal 16⅝ ; with corn, as standard, 4½ per cent. more or 45.7 less weight in grain, and 61, 54, or 40 in flour. Resistance of Dent corn or red wheat may be double that of softer grain ; and thin shell, hard, spring wheat, or tough shell softer winter wheat, differ seriously. Moisture may add 22 per cent. resistance ; grade of flour is also different. So, as to extremes, and not as to uniform conditions. D'Aubuisson (p. 449) concludes that "with the same fall, water, and stones," or power, "the quantity ground may vary as three to one."

Since 1870, the purifying and regrinding machinery has been added, and better machinery has been made for the same work.

Usual work : Taking wheat flour as standard, the power per run depends on the quantity ground, for which a moderate standard, determined from a large number of mills, was taken at ten bushels per hour.

The shaft power, deduced from a number of cases, for the best modern mills, for ten bushels per hour, was taken as a minimum at 7.5 horse-power for grinding, 4.5 mill machinery, wheel (75 per cent.) 4, or 16 "water" horse-power in all.

Mill work of 1840 : Except at a few centres, where active demand justified expensive wheels, pits and machinery, much less perfect wheels and machinery were used, and greater power required.

The horse-power standard of leading authorities in mill-work of that day was above that of the present. Buchanan's Millwork, 1841, uses 44,000 foot-pounds ; Desagulier, the same ; Watt, in practice, also ; Evans (Millwright's Guide, p. 117) quotes 41,555 foot-pounds British test ; D'Aubuisson takes 40,202.

About 1 horse-power per bushel per hour, or 1.22 to 1.33 standard, has been generally assumed as the grinding work of a "run."

D'Aubuisson assumes, for wheat, 1.29 horse-power (standard), for grinding alone ; a British government experiment quoted is 1.29 (standard).

For " water"-power, ten cases cited by him, including mill machinery, average 4.744 horse-power per bushel for 33.8 per cent. average wheel duty, or 2.672 horse-power at 60 per cent., or 26.72 for 10 bushels per hour, this being the duty of the best Lowell wheels. Among these cases, Providence mills, 2.414 horse-power per bushel; Bayard, Toulouse, 2.96 horse-power (wheel, 43 per cent.), and a number of United States mills (from Evans) of 3.14 average, with 41 per cent. wheels.

Evans (p. 106), 5-foot "run," 97 revolutions, grinding only, 2.56 horse-power "water;" p. 111, 2.61 horse-power; p. 174, overshot, 4.63 horse-power per bushel "water," at 60 per cent. wheel, 2.778 horse-power "shaft."

In an Oswego case, an award gave with a Reynolds wheel (worth about 40 per cent. part gate, 50 per cent. whole gate), 38.59 horse-power rate for 2,000 cubic feet on 10-foot fall.

This gives, for grinding, an increase from 7.5 horse-power "shaft" of best modern mills to 12.5 to 26; and for wheels, runs and machinery, an increase from 16 to 24, 25.6, 26.1, 29.6, 31.4 and 47.4 horse-power, with wheels of varying duty and poorer machinery.

The deduction was 12 horse-power wheel (60 per cent). 13 grinding and 5 machinery, or 30 horse-power in all, or 18 horse-power "shaft;" ordinary wheels, not over half this duty.

Local conditions: In connection with this analysis it was shown that no local demand existed for any higher class of wheels or mills than those used for this or similar races, and any "skillful" engineer would adapt his structures to their uses at the time and place. With one railroad, to Lockport only; a canal not enlarged until 1852, 1,277 population in 1840 and 1,468 in 1850. and a superabundance of water, expensive wheels and pits would have been out of place. Undershot. tub. scroll, and wheels of that class were generally in use, with 16 to 33 per cent. duty.

Power in use: A race measurement showed 10,350 cubic feet water per minute. used with 3, of 5 grinders, operating without the electric wheel on, for a virtual fall of 16½ feet or 320 horse-power water, 240 "shaft;" full mill use would take about 400 horse-power "shaft," plus 12.23 for light, the rated wheel-power being 425.

Judge Peck's decree allots for the original head of 8½ ft. on Hill & Murray (increased by them to 17½), 20 horse-power "per run" for wheels of 30 per cent. duty, or 4.152 cubic feet per minute, or for 7 runs 29.064 cubic feet per minute. For wheels of 75 per cent. duty now in use, this, at 16½ feet head, equals about 679 horse-power.

Value: In the testimony on this point it was claimed, that while water-powers have no common "market value," in the sense of frequent advertisement of rates and transfers, and valuable powers were scarce, the actual value should be judged by the local conditions above named, and by the rates which have been paid at similar milling centres for similar power, as at Lowell, Cohoes, Holyoke, Paterson, Philadelphia, etc.

The old standard lease rate of Lowell, Lawrence, Cohoes and Holyoke is practically about $20 per horse-power "shaft" rent per year for mills usually running 10 to 11½ hours per day. At the "Belvidere," Lowell,

from 1876, the time is limited to 10 hours; in these cases a low rate is asked to induce sales of lands and population increase, the practical rent of Lowell being about $36.50 per horse-power at the mills. The "Essex,' Lawrence, and other mills, let rooms and power at $75 per horse-power, room additional; 8 cents per square foot sometimes.

Mill Power Standards.—Lowell: Right to draw, during 15 hours in each day of 24, 25 cubic feet per second, at upper fall, when head and fall is 30 feet (low water 33 feet): 60.5 cubic feet on 13 feet middle fall (low water 14 feet); 45.5 cubic feet on 17 feet, lower fall (low water 19 feet): "shaft" power taken at 60 horse power.

Wamesit dam, Concord River: 27 cubic feet per second on fall 21.89 to 24.97 feet; average, 23½ feet; time limit, 11¼ hours. Rated, 27 horse-power; price, $2,750 rent.

Lawrence: 30 cubic feet per second, on 25 feet head and fall, limit 16 hours per day, varying with actual fall, less 1 foot. Ordinary summer fall, 28 to 29 feet.

Cohoes: Orifice, 50 inches by 2 inches, under 3 feet head and 17 feet fall, 6 cubic feet per second; rent, $200; about $\frac{120}{750}$ Lowell power; 3 falls of 20 feet, virtual.

Patterson: Orifice, 24 inches by 6 inches, 3 feet head and 19 feet fall, 8½ cubic feet per second, 21.19 horse-power "water," 15.9 "shaft"; rent, $750, $47.18 per horse-power "shaft;" 3 falls of 22 feet, virtual.

Manayunk, Pa.: 3 feet head and 18 feet fall, 24 hours, $6 per square inch; $56.25 per horse-power "shaft."

Birmingham, Conn.: 1 square foot, 5 cubic feet per second, 12.5 horse-power, 12 hours; rent, $250, $20 per horse-power.

Dayton, O.: 15 inches head, 233⅓ cubic feet per minute, 1 run or power, 3 falls; 300 cubic feet per minute on 12 feet; 5.25 horse-power "shaft;" rent, $200, $38 per horse-power. On the "Lower race," for an actual use of about 64 horse-power, $1,815 rents were paid, including structures; one tenant paid $550, using 10 horse-power about ten hours. In our water-supply appropriations for cities, our notes show over $100 per horse-power paid in various cases.

Rentals of steam-power much exceed those of water; $2 and $3 per week are common rates; the Sears estate, Boston, gets $175 per year; at Lowell the lowest price is $100, and the "Central Pacific" mill, with 1,000 horse-power, steam, prefers to pay $60 per horse-power annual rate for extra water, for "months together," to running its engines (Sudbury River Case, p. 73). To substitute equal steam-power, in another location, would cost $21,250 annually to Hill & Murray, or $425,000, capitalized at 5 per cent.

On the other hand, the proprietors of the Hydraulic Canal, having bought it for a small sum, to induce tenants, have made several very low leases; one has a sliding scale of $4 per 600 to 1,000 horse-power up to $5.30 for 250 to 300; other leases are $5 and $10; but the supply is not fully maintained. A recent applicant has been charged $25, without guarantee; and I am retained in a case where power for additional machinery provided, has been refused.

Mr. Herschel's testimony shows: Holyoke, power delivered by day 15,000 horse-power, night 8,000; about 70 tenants; investment about

$3,000,000 ; population 30,000 ; day and night price, $40 per horse power, Hill & Murray power equal to 8 Holyoke mill-powers each of 60 horse-power " shaft," worth $30,000 each, or $240,000.

My valuation was for a minimum of 320 horse-power "shaft," at $40, $12,800 rent, or $256,000 capital, at 5 per cent. Valuation of lands, $26,000 ; mill, $13,000 ; machinery, $30,000.

The State award was $81,690 for the entire claim, of which, it is said, the allowance for water-power was based on 105 horse-power at $10. This is another illustration of a curious experience in public works, under which men of the highest character, individually, when acting jointly sometimes seem to mutually disintegrate the plainest conclusions of duty to sufferers under the law of "eminent domain."

THE WELLESLEY WATER-WORKS.

By Frank L. Fuller, Member of the Boston Society of Civil Engineers.
[Read June 17, 1885.]

Of the many advantages to be derived from a pure and abundant water supply, but little need be said. It has come to be a necessity, not only for cities, but even for villages and country towns. Modern mechanical appliances and improvements have made it so easy to raise water from its original or natural level and distribute it through pipes of proper size to all parts of a town or village, that water under pressure, although a luxury, is not an expensive one.

No man can afford to dig a well or build a cistern, when for the interest, or even less than the interest, on this outlay, he can have all the water he wants by simply opening a faucet. He saves the annual cost of repairs on pumps or other device for raising the water, and what is of far greater importance, is certain that it is not contaminated by the drainage from his own or neighbor's house.

In hot and dusty weather the sprinkling of streets and lawns is indeed a luxury ; and it cannot but be a source of satisfaction to know that in case of fire, there is, close at hand, a comparatively inexhaustible supply of water which can be thrown upon the highest building. Public buildings and private houses can be so supplied with hose that almost immediately upon the discovery of fire, water can be thrown upon it.

There is often more or less opposition to the introduction of water into a town, but a short time is sufficient to convince even the strongest opponent of its advantage to a community, and no town or city once having enjoyed these benefits could be induced to give them up.

The first work in the way of engineering was done in the spring and early summer of 1883. On May 29, the first test or driven well was begun near Charles River, just below the dams at Newton Lower Falls. The object was to find a locality where the soil should be of such a coarse, gravelly nature as to give indications of a good supply of ground water or water filling the interstices of the soil. Four test wells were driven at the locality mentioned, but the indications were not altogether favorable. On June 7, a fifth well was begun at Wellesley, near Charles River,

S. W., and not far from "Waban Valley Bridge," on the New Sudbury River conduit. The yield of water at this point was good, especially after reaching a depth of twenty feet, but the material was almost entirely quicksand, and there seemed, in the minds of some, to be a possibility of endangering the abutments and piers of the bridge by doing anything which might set the sand in motion. During the driving of these wells, accurate levels were taken over that portion of the town where it was expected pipes would be laid. The following were determined later, and are perhaps the only ones of general interest:

Charles River at pumping station	65.0
Floor of pumping station	72.0
Centre of water-gauge in engine room pumping station	78.92
High water in reservoir	324.0
Top of reservoir bank	328.0
Floor of reservoir gate house	329.4

The base adopted was mean low water in Boston Harbor, which could be easily obtained from benches on the new Sudbury River conduit, which passes through the town.

During the autumn of the same year (1883), the Water Committee made an excavation about 10 feet square and 5 feet deep, about 65 feet from Charles River. This was at a point about 1,000 feet further north than the test wells before spoken of. As tested by pumping, they found the yield to be at the rate of about 225,000 gallons in 24 hours.

During the latter part of January, 1884, it was decided by the Water Commissioners who had been chosen, to drive test wells near Charles River, near the excavation which had been made, and between the dates of February 11 and 20 seven wells were driven. The method followed was to first drive an open end pipe 2½ inches in diameter, the lower end of which had been properly hardened, by means of a block of cast iron weighing about 112 pounds. Attached to this block was an iron rod about an inch in diameter and four feet long, which moved up and down inside the pipe, acting as a guide as the iron block or hammer was raised and allowed to drop. This was done by means of shears placed over the spot where it was desired to drive the pipe. To the shears was attached a tackle, by means of which two men lifted the iron hammer two or three feet, and suddenly dropping it, drove the pipe into the ground. After driving from one to four feet, according to the soil, the material inside the pipe was removed for inspection, by introducing a 1¼-inch pipe to which was attached a pump.

By means of a force pump, placed near the river, water was pumped through hose into the space between the large and small pipes, and the material in the former pumped out in a semi-fluid condition.

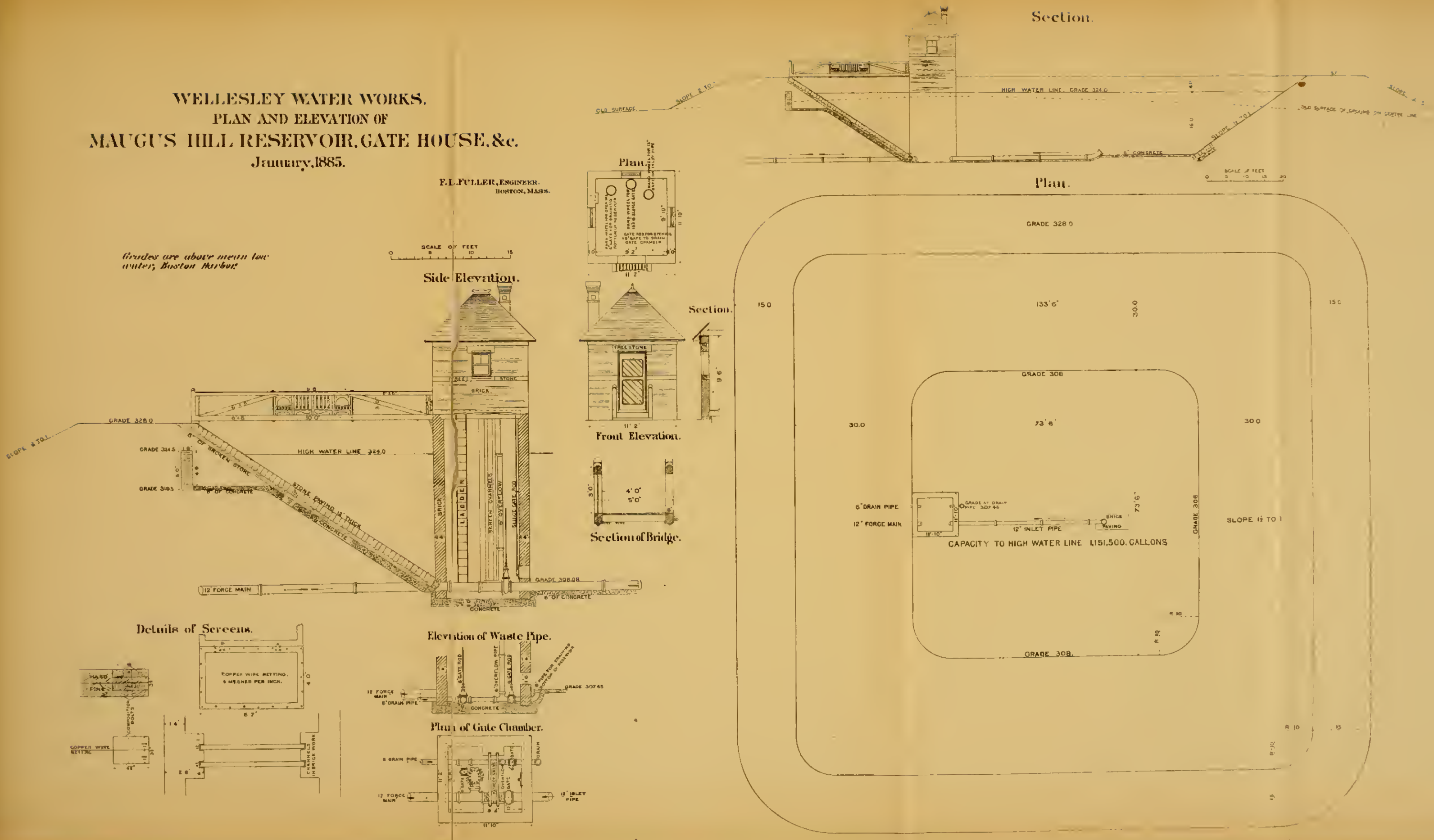
In this manner very coarse gravel and pebbles could be raised. A drill was also used where the material was very coarse. It was so made that water could be forced through it, and by raising and turning it by means of a cross-head, the material was loosened and forced out by the water.

A sufficient number of samples from each of the wells driven were preserved for comparison and reference. Some of the wells driven at the locality mentioned were satisfactory, but as a general thing the indications were that the material was largely quicksand, and to that extent not desirable.

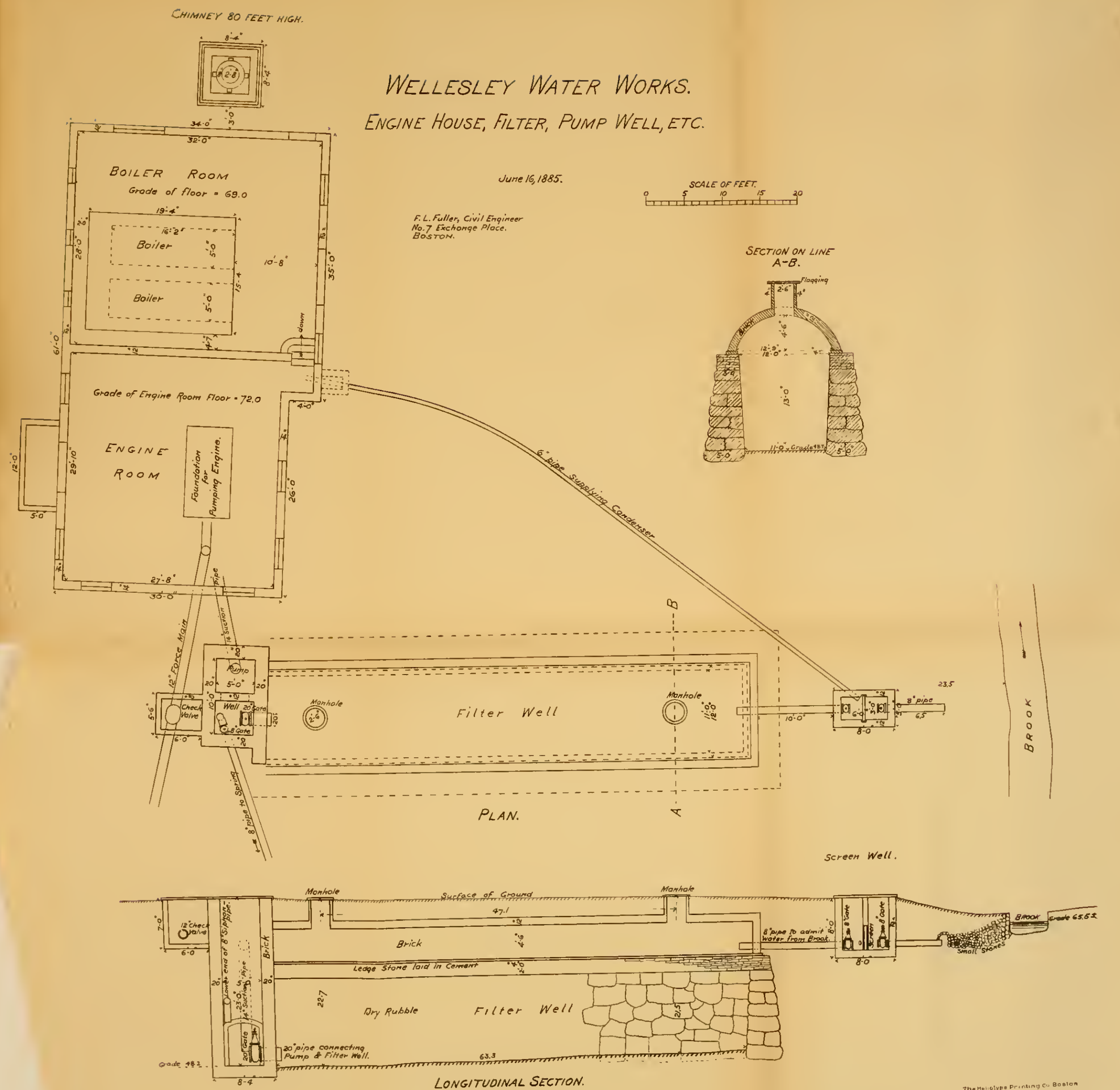
WELLESLEY WATER WORKS.
PLAN AND ELEVATION OF
MAUGUS HILL RESERVOIR, GATE HOUSE, &c.
January, 1885.

F. L. FULLER, ENGINEER.
BOSTON, MASS.

Grades are above mean low water, Boston Harbor.



The Heliotype Printing Co. Boston



WELLESLEY WATER WORKS.
ENGINE HOUSE, FILTER, PUMP WELL, ETC.
June 16, 1885.
F. L. Fuller, Civil Engineer
No. 7 Exchange Place.
Boston.
SCALE OF FEET.
0 5 10 15 20
CHIMNEY 80 FEET HIGH.
BOILER ROOM
Grade of floor = 69.0
Boiler
Boiler
Grade of Engine Room Floor = 72.0
ENGINE ROOM
Foundation for Pumping Engine.
6" pipe supplying Condenser
12" Force Main
14" Suction
Check Valve
Pump
Well
Filter Well
Manhole
Manhole
8" pipe to Spring
8" pipe
BROOK
PLAN.
SECTION ON LINE A-B.
Flagging
Brick
Screen Well.
Surface of Ground
Monhole
Manhole
12" Check Valve
Lower end of 8" Siphon-pipe.
14" Suction Pipe
Brick
Ledge Stone laid in Cement
Dry Rubble
Filter Well
20" pipe connecting Pump & Filter Well.
8" pipe to admit water from Brook.
Small Stones
BROOK
LONGITUDINAL SECTION.
The Heliotype Printing Co. Boston

Four test wells were then driven on land south of the Cochituate aqueduct Bridge. The soil proved stiff and compact, and ledge was found at from 11 to 20 feet feet. This location not proving satisfactory, the next wells were driven a little higher up, near Charles River. Five wells were driven on the south side of the brook from Longfellow's pond, not far from Charles River. Eight wells were then driven on the north side of the brook, and March 25 an excavation of 16 × 10½ was begun. By means of street piling this was carried down about 13½ feet. A 6-inch Heald and Sisco centrifugal pump was used for pumping the water out, and as nearly as could be computed from rather rough measurements, which were the best at our command, the yield was at the rate of about 100,000 gallons in 24 hours.

April 23 the Commissioners decided to locate the filter well, as it is now built, on the northwest side of the brook from Longfellow's pond, and about 400 feet from Charles River. An examination of the banks of Charles River at Wellesley, between the Needham and Wellesley line and Waban Valley Bridge, was made, but no test wells driven. April 25 the filter well was staked out, and work begun by days' labor. After the excavation had been carried down to a depth of about 20 feet, it was inclosed with a heavy dry stone wall, 5 feet thick at the bottom and 2½ at the top. The width at the bottom, 11 feet, and at the top, 12; the length 63 feet. Through the openings in this well the water enters as well as at the bottom. At the northerly end is located the pump well, 5 × 10 feet. It is of brick work 20 inches thick, and is connected with the filter well by means of a 20-inch gate. An 8-inch pipe, with a gate of the same size connected with it, was laid through the west end of this well to connect with an 8-inch pipe line to a spring about 900 feet southwest on land bought of the heirs of Nancy C. Williams. An 8-inch quarter bend and a piece of 8-inch pipe, reaching nearly to the bottom of the pump well, forms the lower end of a siphon, which when completed will furnish an additional supply to the pumping engine. At the south end of the filter well, between it and the brook, is a small screen well, 3 feet × 6 feet, into which the water of the brook can be admitted through an 8-inch pipe. After passing through a copper wire screen, a second 8-inch pipe allows it to pass into the well. Both of these pipes are ordinarily closed by an 8-inch gate on each pipe. A third pipe, 6 inches in diameter, from this well supplies water to the condenser of the pumping engine. The filter well is covered by a brick arch 12 inches thick, 12 feet 9 inches span, and 4 feet 6 inches rise. The pump and screen wells and two man-hole openings for entering the filter well are covered with heavy flagging stone.

April 23, 1884, the centrifugal pump was set up at an excavation which had been made at the spring before referred to, on the Williams land. This excavation was about 18 feet × 29 feet at the water surface, and about 6 feet deep. The water was pumped into a large box, in one side of which was placed a weir for measuring the flow. It was found difficult to so regulate the engine as to keep the water at the same level in the excavation for any length of time, in order to estimate the yield of the spring. As nearly as this could be done, it was found to be at the rate of 300,000 gallons in 24 hours. The material that was excavated was

clean, coarse gravel, and the appearance indicated a permanent and plentiful supply of water. The water is perfectly clear and colorless, and has a temperature of 48°. A weir was put in, and the natural flow of the spring found to be 87,000 gallons in 24 hours. By sinking a proper well at this point, a large supply can be obtained.

PIPE.

Specifications for cast-iron water pipe and for laying the same were prepared, and proposals invited by advertising. On May 20, the date fixed, 21 bids for laying and four for furnishing pipe were received. The bids for laying pipe ranged from $16,465 to $52,507. The bids for furnishing pipe varied from $58,280.11 to $65,282.

On July 7, the contracts for furnishing and laying about 1,500 tons of pipe were awarded to John T. Langford, of Newton, at the following prices:

Cast-iron pipe, per gross ton	$36.00
Special castings	67.00
Laying 12-inch pipe, per lineal foot	36
" 10-inch " "	30
" 8-inch " "	25
" 6-inch " "	20
" 4-inch " "	17

which prices include, according to the specifications, the setting of all gates, hydrants, special castings, bridge, brook and railroad crossings.

Some difficulty was experienced in obtaining pipe from the foundries as promptly as was desired. Mr. Langford, by using a quantity of pipe he had on hand, and laying the first pipe in the ledgy portions of the town, was able to begin pipe-laying August 4. All of the pipe, except that first mentioned, was from the foundry of A. H. McNeal, Burlington, N. J. The first pipes were cast about August 1. The pipe has so far proved to be of the best quality. But four leaks were discovered in a length of 13.18 miles on letting on the water and submitting the pipe to a pressure of 200 lbs. per square inch at the pumping station, and only only one was from a cracked pipe. The specifications required a tensile strength of 16,000 lbs. per square inch., with the provision that bars 1 inch square, taken as often as required, should be furnished by the manufacturer for use in testing. This was not required. The following figures, from tests made at the foundry, show that the iron considerably exceeded the strength called for:

TENSILE STRENGTH OF CAST-IRON AS DETERMINED AT FOUNDRY OF A. H. MC NEAL.

August—Highest	24,350	Sept.—Highest	24,850	At highest	25,700
Lowest	19,380	Lowest	18,680	" lowest	20,000
Av. of 23 specimens	22,213	Av. of 20 specimens	22,781	Av. of 25 specimens	22,917

The special castings, consisting of Ts, Ys, bends, reducers, gate boxes, etc., were furnished by the Builders' Iron Foundry, of Providence, R. I., and were of excellent quality. The pipes are laid generally on the north side of streets running east and west, and on the east side of streets running north and south. River street is an exception; there being no houses on the north side, the pipe is laid on the south side. On wide streets, the pipe is generally laid about 15 feet from the street line; on narrow ones, it is from 10 to 13 feet away. There is generally more sun on the north and east sides of streets, and the frost does not go as deep.

The gas pipes as laid in the town of Wellesley are on the south and west sides, and are therefore avoided in digging trenches for water pipe. All pipes are laid with a covering of five feet to top of pipe.

The length and size of pipes and the streets in which they are laid, are shown by the following table :

STREET.	12 inches.	10 inches	8 inches.	6 inches.	4 inches.	Total.
Allen			657.5			657.5
Blossom				5,804.4		5,804.4
Cedar	1,998.0			70.3	1,512.5	3,580.8
Cedar to pumping station	780.0			12.0		792.0
Central avenue			1,058.0	852.0		1,910.0
Chestnut				1,388.0		1,388.0
Columbia					1,393.2	1,393.2
Cottage				2,045.5		2,045.5
Elm					937.5	937.5
Everett				253.4		253.4
Florence avenue				1,322.5		1,322.5
Forest avenue				1,451.7		1,451.7
Front				1,066.8		1,066.8
Glen Road					1,618.5	1,618.5
Grove				3,711.6		3,711.6
Kingsbury					2,301.9	2,301.9
Laurel avenue					1,303.8	1,303.8
Linden				35.0	949.3	984.3
Maugus avenue	1,461.4			152.2		1,613.6
Oakland				850.1		850.1
Private way near J. Beck's				255.0		255.0
River				1,923.8		1,923.8
Rockland				1,038.7		1,038.7
Walnut	3,705.0			1,130.1		4,835.1
Washburn				45.6		45.6
Washington	3,873.0	7,601.5	2,815.2	6,347.7		20,637.4
Wellesley avenue				73.2		73.2
Woodlawn avenue				2,960.5		2,960.5
Worcester				2,809.1		2,809.1
Total in feet	11,817.4	7,601.5	4,530.7	35,599.2	10,016.7	69,565.5
Total in miles	2.24	1.44	0.86	6.74	1.90	13.18
Per cent	17	11	7	51	14	100.

TABLE OF THICKNESS, WEIGHT, JOINT ROOM, ETC.

Inside diameter in inches.	Class.	Joint room in inches.	Depth of socket in inches.	Depth of lead. Inches.	Weight per foot. Lbs.
12	A	.5	3.5	2¼	70
12	B	.5	3.5	2¼	77
12	C	.5	3.5	2¼	85
10	..	.5	3.5	2¼	65
8	..	.4	3.5	2	45
6	A	.4	3.0	2	31
6	B	.4	3.0	2	33
4	..	.4	3.0	2	20

The weights are proportioned to the pressure ; the lighter weights of 12 inches are on Maugus Hill, where the head is least, and the heaviest at the lower level toward the pumping station. Class B of the 6 inches is laid at the Lower Falls, where the pressure is greatest. But one class of 4 inches was used, that being considered heavy enough for any part of the town.

GATES.

The system of distribution is well divided into sections by the use of stop gates. They are to be used in shutting off the water in case of acci-

dent, repairs and extensions. They have been arranged to do this by shutting off as few takers as possible. Their locations are shown by detail plans, which also show the plugged branches put in for future extensions. The following is the total number of each size used : 1 20-inch, 7 12-inch, 4 10-inch, 7 8-inch, 41 6-inch, 15 4-inch. They are mostly of the Ludlow pattern, a few Chapman having been used. No trouble in the working of either has so far been experienced.

HYDRANTS.

All hydrants are of the Ludlow pattern, made at Troy, N. Y. There are four with four $2\frac{1}{2}$-inch nozzles, having independent gates. Two are at Lower Falls, one at Wellesley Hills, and one at Wellesley Square. The remainder have two $2\frac{1}{2}$-inch nozzles for hose connections. Most of them have a 4-inch inlet gate and stand pipe $5\frac{3}{4}$ inches internal diameter. A few have a 5-inch inlet and a 7-inch stand pipe. The location of all hydrants thus far set and the pressure when the reservoir is full is given below. There are in all 67 hydrants, five of them being private.

LOCATION OF AND PRESSURE AT HYDRANTS.

Pressure due to full reservoir, given in lbs. per sq. inch.

Blossom st.,	near	Washington st	73
" "	"	J. T. Johnstone's	73
" "	"	I. M. Jones'	69
" "	"	J. A. Porter's	70
" "	corner	Worcester st	72
Cedar "	"	" "	91
" "	near	Oliver Morse's	98
" "	"	W. R. Dimond's	90
" "	"	Pumping station	109
Central ave.,	"	Hunnewell school	76
Chestnut st.,	"	I. Nash's	52
Columbia "	"	George Springs	109
Cottage "	"	Shoe shop	74
" "	"	H. A. Fisher's	82
Elm "	"	H. McLeod's	65
Everett "	"	Town Hall	76
Florence ave.,	"	B. F. Parker's	40
Forest "	corner	Washington st	70
" "	"	Seaver "	79
Front st.,	"	Curve "	71
" "	near	East end	68
Glen Road,	corner	Washington st	102
" "	near	E. H. Whitney's	99
Grove st.,	"	Dana Hall	82
" "	opposite	Cottage st	80
" "	corner	Benvenue "	69
Kingsbury st.,	"	Washington st	77
" "	near	J. Welch's	72
" "	corner	Worcester st	72
Laurel ave.,	near	D. W. Cunningham's	79
Linden st.	"	J. G. Abbott's	74
Maugus ave.,	"	F. F. Baldwin's	63
Oakland st.,	corner	Washington st	66
" "	"	Worcester "	53
" "	near	Geo. W. Hollis'	46
River "	"	J. Pulsifer's shop	115
" "	"	Mrs. Fitzgerald's	112
Walnut "	"	Charles River	109
" "	"	Mrs. Joy's, 4-way	101
" "	"	Arch Bridge	90
" "	"	G. N. Smith's	69
Washburn st.,	corner	Walnut st	68
Washington st.,	near	Lower Falls, railroad station	114
" "	"	Crescent st	83
" "	"	W. F. Norcross'	64

Washington st.,	opp. Wellesley Hills Cong. Church	68
" "	near Maugus ave	74
" "	" Wellesley Hills railroad station	75
" "	" Charles Kingsbury's	75
" "	" A. H. Buck's	76
" "	at Wellesley Square, 4-way	80
" "	near E. F. Wiswall's	75
" "	" J. Gray's	73
" "	" Waban Brook	87
" "	" H. H. Hunnewell's	75
" "	" Pond Road	83
Wellesley ave.,	cor. Washington st	82
Woodlawn "	near Thos. Cogswell's	68
" "	" J. E. Fiske's	67
Worcester st.,	cor. Washington st., 4-way	70
" "	opp. Chestnut st	69
" "	Rockland "	52

PRIVATE.

Billings, Clapp & Co.'s yard	119
R. T. Sullivan's yard	118
Dudley Hosiery Co.'s yard, No. 1	114
" " " " 2	115
" " " " 3	116

RESERVOIR.

August 19, 1884, ground was broken for the reservoir. The stumps, roots and light materials were removed from an area somewhat larger than that to be covered by the reservoir. The stumps were piled together, to be burned when dry. The loam and light materials were piled where they would be convenient to use in soiling the outside of the slopes. As soon as the site had been cleared of stumps, soil, etc., an estimate was made of the amount removed, and the excavation for the reservoir was begun Sept. 8. The grade of the top of the banks had been so fixed that the excavated material should as nearly as possible make the embankments without having to borrow extra material or to waste any of that excavated.

The reservoir is located a little to the north of the highest point on Maugus Hill, about 1,500 feet from Washington street. The hill is well located to answer the purpose of a reservoir site, being of good elevation and very accessible. The reservoir is 133 feet 6 inches square at the top and 73 feet 6 inches at the bottom. At both top and bottom the corners are rounded by circles 10 feet in radius. High water is 16 feet above the bottom of the 18-inch square inlet at the rear of the gate chamber, and the contents when the water is at this level are 1,151,573 gallons.

The general arrangement of the reservoir is shown by the plan. The 12-inch force main passes through the embankment at a grade of about one foot in 100, so that when the reservoir is drawn down, the force main can also be entirely emptied by opening the hydrant on Maugus avenue. As shown on plan, the top of embankment is at grade 328 above mean low water, Boston Harbor, or Boston city base, and the bottom at the sides at 308. The banks are 15 feet wide on top. The inside slope is 1½ horizontal to 1 vertical, or at an angle of 33 deg. 41 min. with the horizontal. The outside slope is 2 to 1—that is, 2 horizontal to 1 vertical, or at an angle of 26 deg. 34 min. with the horizontal. The outside is covered with the loam removed from the reservoir site, and seeded down to lawn grass. The inside, when the excavation had been carefully dressed to line to give the exact slope on the sides and rounded corners,

WELLESLEY WATER-WORKS—CAPACITY OF MAUGUS HILL RESERVOIR.

	No. of Gallons required to fill Reservoir when water is of the level of line upon which figures are written.		No. of Gallons in each foot in height of Reservoir.	Per cent of total Capacity.	No. of Gallons in Reservoir when water is at the level of line upon which the figures are written.	
High Water	0	16		100	1,151,573	Grade 324.12
	107,269	15	107,269	91	1,044,304	
	209,204	14	101,935	82	942,369	
	305,939	13	96,735	73	845,634	
	397 609	12	91,670	65	753,964	
	484,348	11	86,739	58	667,225	
	566,291	10	81,943	51	585,282	
	643,573	9	77,282	44	508,000	
	716,329	8	72,756	38	435,244	
	784,693	7	68,364	32	366,880	
	848,799	6	64,106	26	302,774	
	908,783	5	59,984	21	242,790	
	964,779	4	55,996	16	186,794	
	1,016,921	3	52,142	12	134,652	
	1,065344	2	48,423	8	86,229	
	1,110,183	1	44,839	4	41,390	
	1,151,573	0	41,390	0	0	Grade 308.12 = Bottom of 18" Opening in Gate Chamber.

F. L. Fuller, Engineer.

was covered with a layer of 10 inches of concrete, made of 2½ parts of broken stone or screened gravel to 1 part of cement mortar, made of 1 part of F. O. Norton's cement to 2 parts of sand, or in the proportion of 1, 2, 7½. Over the concrete is a layer of broken stone six inches in thickness, and over this was carefully laid the stone slope paving, 12 inches in thickness. The concrete is for the purpose of making the banks water-tight, and prevents the water from washing down and into the reservoir the clayey material of which the banks are composed. The broken stone and stone paving protect the concrete from frost and the wearing effect of ice in winter and the wash of the waves. On three sides—the east, north and west—the concrete is carried into the bank, as shown on sectional view of reservoir bank. The bottom of the 6-inch horizontal layer is at grade 319.5, or 4½ feet below high water, and is carried into the bank 10 feet to the face of the priming wall. This wall is 18 inches thick and 5 feet high, its top being 6 inches above high water. The wall on the north side was built of concrete; that on the east and west sides of small stone carefully laid in cement. This wall was everywhere plastered on its inside face with ordinary cement, and then received a wash of pure Portland cement applied with a brush, to make it as nearly water-tight as possible. After the horizontal layer of concrete and the priming wall had had time to set, the required filling was put in and well rammed by hand. This earth filling and the broken stone and stone paving will protect the concrete and priming wall from frost, if the water is kept well up to high-water line, which should be done during cold weather.

In future years, as the consumption increases and it becomes necessary to pump daily, the amount of ice in the reservoir will probably be decreased by the comparatively warm spring water pumped in. The bottom is covered with 6 inches of concrete, which slopes in all directions toward the 6-inch drain pipe, put in for the purpose of draining the bottom when it becomes necessary to clean the reservoir. The 12-inch force main passes through the gate chamber and discharges about 38 feet from the gate house. A one-eighth bend turns the current slightly upward, away from the bottom, and offers but little additional resistance. In the gate chamber, which is 9 feet 2 inches by 8 feet 6 inches inside at the bottom, there are two 12-inch check valves and one 12-inch gate, all connected with the 12-inch force main. There are also two 6-inch gates connected with the 6-inch drain or waste pipe. These are all shown on the plans. As the water is forced toward the reservoir, it pushes open the check valve which is on the line of the force main; and when there is no pressure toward the reservoir, the valve falls upon its seat and prevents any water returning through it. At the same time the pressure has been opening the first check valve, it has kept firmly closed the second, which is connected to the force main by a T just before reaching the first check valve, and is at right angles to it. The second valve only opens when the pressure is from the reservoir, being hung to swing in somewhat the opposite direction.

In the rear of the gate chamber is an opening in the brick-work 18 inches square, which can be opened or closed by means of a sluice gate, which is moved by means of an iron rod, which has a screw cut upon it, and a hand-wheel in the gate house. Between this opening, through

which all the water leaving the reservoir must pass, and the second check valve, through which it enters the pipes again, are two sets of copper wire screens of No. 17 wire, ¼ inch mesh. There are four separate screens in each set, so arranged that they can be raised and cleaned. This makes it impossible for any water to return to the pipes without passing through the screens, and of course prevents any leaves or other refuse entering the distribution from the reservoir. The check valves, sluice gate, screens, hand-wheels and stands for the same were furnished by the Coffin Valve Co., of Boston, and are of thorough and substantial workmanship. Three stay or cross-walls of masonry are built across the trench and around the pipe near where the pipe line leaves Maugus avenue. These walls are some distance apart, and serve to intercept the water following down the pipe line, which is carried by drain pipe laid diagonally across the street to the gutter on the west side. In case of a break above, these walls would in some measure prevent the damage and danger from wash that would be likely to occur. The brick walls of the gate chamber are 16 inches thick, laid in cement. At grade 328.4, or 0.4 above the the top of the embankment, the walls are reduced on the inside to 12 inches, which is the thickness of the gate house. On the inside, the gate house is 9 feet 10 inches × 9 feet 2 inches, and on the outside 11 feet 10 inches × 11 feet 2 inches. The grade of the floor is 329.4, or 5.4 above high water. The gate chamber and gate house are of good quality hard-burned brick. The gate house is built at the foot of the inner slope of the reservoir, and is connected with the top of the bank by a bridge.

PUMPING STATION.

Plans and specifications for a brick and freestone building to contain pumping engine and boilers, and also a chimney 80 feet high, were prepared by Mr. E. N. Boyden, architect, Boston. October 4, ten bids were received for furnishing all materials and doing all the labor required in erecting building and chimney, ranging from $5,109 to $6,575. The lowest bidder was W. E. Scribner, of Auburndale, and he was awarded the contract. Some delay was experienced in receiving the granite base. Work was begun in October, and progressed fairly until its completion.

The engine room is 27 feet 8 inches × 29 feet 10 inches inside, and the boiler room 32 feet × 28 feet. The chimney is 8 feet 4 inches square at the base, and has a foundation and belt course of granite. The foundation is 12 feet square and 8 deep. It has a round core 32 inches in diameter. The top is capped with a heavy course of freestone, over which is set an iron cap 5 feet square, with opening same size as core. The engine room is made large enough to accommodate an additional pumping engine when it shall be needed.

Just outside the building on the force main is a 12-inch check valve, which closes when the pump is not at work, and relieves it of pressure. Connected with it is a Y, one branch of which is plugged until another pumping engine is required, as explained above. Then another check valve will be attached to the now plugged branch of the Y and 12-inch pipe connect it with the new pump. The present check valve is in a small brick chamber, so as to be easily accessible. Beyond the check valve, 60 feet from the building, is a 12-inch gate, which can be closed

when it is necessary to repair check valve or the hydrant near by. The walls of the engine room are 14 inches thick, with a 2-inch air space. The boiler room walls are 12 inches thick and solid. The foundation walls of the building are 2 feet thick, and vary from 5 to 7 feet deep. All were built of ledge stone.

PUMPING MACHINERY.

This consists of one compound condensing duplex pumping engine, made by the Geo. F. Blake Manufacturing Co., of Boston ; high-pressure steam cylinder. 12 inches diameter ; low-pressure cylinder, 22 inches ; water plunger, 10 inches ; length of stroke, 18 inches. It has an independent air pump and condenser. Each stroke displaces 5.89 gallons, and therefore to pump 1,000,000 gallons in 24 hours, its capacity, there are required 117 strokes per minute, or a piston speed of 88 feet per minute.

The boiler room contains two horizontal boilers, made by the Whittier Machine Co., of Boston. They are each 16 feet long, 60 inches in diameter, and have 80 tubes 2¾ inches in diameter, 15 feet long. If the heating surface is taken as the area of one-half the shell and the whole interior area of the tubes, it amounts to 982 square feet. On the basis of 15 square feet of heating surface per horse-power, they are of 65.4 horse-power.

The power required to pump 1,000,000 gallons into the reservoir in 24 hours, or against the pressure caused by full reservoir, is about as follows:

1,000,000 gallons in 24 hours = 694.44 gallons per minute.

Wt., one gallon at 50° = 8.34 lbs.

Lift, not including friction = 264 feet.

1 horse-power = 33,000 foot lbs., or 33,000 lbs. raised one foot per minute.

$$\frac{\overset{\text{Gals.}}{694.44} \times \overset{\text{Wt.}}{8.34} \times \overset{\text{Lift.}}{264}}{33,000} = 46.3 \text{ horse-power.}$$

SERVICE PIPE.

There is great diversity of opinion in regard to the best material for service pipes for water. That adopted was tar-coated wrought iron. Its advantages are its cheapness, the facility with which it can be laid, and that it has no unwholesome effect upon the water. The question of its durability remains to be proved. The experience of some towns has been that the coating, not adhering as firmly to the wrought iron as to the cast, leaves the pipe exposed, and the action of rust begins.

DUTY TEST OF PUMPING ENGINE.

April 25, 1885, a rather informal test was made of the Blake pumping engine. Fires were started at 5:45 A. M., and at 8:30; the engine started with 67 lbs. of steam. Observations were taken of the steam and water pressure, counter, vacuum, depth of water in pump well. At first the observations were taken every five minutes. From 10:30 A. M. to 6 P. M., the close of the test, they were taken once in 15 minutes. The following data are used in calculating the duty :

Area of 10-inch plunger....................	78.54	square inches.
½ area of 2¾ plunger rod....................	2.97	"
Effective area............................	75.57	"

Length of stroke, 18 inches ; one U. S. gallon = 231 cubic inches ; aver-

age water pressure, as indicated by gauge, 113 8 pounds; number of strokes, 60,428.

$$\frac{75.57 \times 18}{1728} = .7872 \text{ cubic foot displaced at each stroke.}$$

$$\frac{75.57 \times 18}{231} = 5.888 \text{ gallons displaced at each stroke.}$$

Coal used in running 9 h. 30 m., 1,734 pounds.

From levels which were carefully checked, it appears that the water-pressure gauge indicated at least six pounds too much.

113.8 — 6.0 = 107.8 pounds.

107.8 × 2.31 = 249.02 feet. Average lift above centre of gauge, including friction.

19.17 Average distance from centre of gauge to water in pump well.

268.19 Total lift in feet, including friction.

Cub. ft. per stroke. Strokes. Wt. 1 cub. ft. water. Lift.

$$\frac{0.7872 \times 60428 \times 62.38 \times 268.19}{1734 \text{ pounds coal.}} \times 100 = 45,894,660 \text{ foot-pounds per 100 pounds coal.}$$

Three hundred and forty-one pounds of coal used previous to 8:30 A. M. in starting the fires, is not included in the 1,734 pounds above. The fire at the close of the test was as nearly as possible in the same condition as at starting. No account of the length of stroke was taken, as would have been done in a more complete trial with a sufficient number of assistants. By carefully regulating the valves, a length of 18½ inches stroke can obtained, but the average during the test was probably not over 18 be inches. The addition of ½ inch to the length of stroke would increase the duty above given by $\frac{1}{36}$, or 1,274,852 foot-pounds, making the duty on this basis 47,169,512 foot-pounds. No allowance or deduction has been made for slip or loss of action, and as the water pumped could not be measured, no estimate could be made of its amount. At Lowell, in 1876, at the trial of the 5,000,000 Worthington engine, the water pumped was carefully measured over a weir, and there was a loss of 2¼ per cent. At a trial of the 3,000,000 Corliss pumping engine, at Pawtucket, in 1878, as determined by careful measurements, the loss was 1.4 per cent. The amount of water pumped during the test was:

Strokes. Gals. per Stroke.

60,428 × 5.9 = 356,525 gallons.

$$\frac{356,525}{9\frac{1}{2}} = 37,529 \text{ gallons per hour average.}$$

To pump at the rate of 1,000,000 gallons in twenty-four hours requires 41,667 gallons to be pumped per hour. The pumping machinery and boilers are of good design and thorough construction, and will no doubt do excellent service.

REMINISCENCES OF THE CONSTRUCTION OF THE NEW YORK, WEST SHORE & BUFFALO RAILROAD.

By Wm H. Searles, Member of the Civil Engineers' Club of Cleveland.

[Read May 12, 1885.]

The project of a railroad along the western shore of the Hudson River was a favorite one for many years before it was finally realized in the splendid property now known as the New York, West Shore & Buffalo Railroad. Up to the year 1872, although several schemes had been started and companies organized for the purpose of building a railroad between Hoboken and Albany, no more progress had been made than to drive lines of stakes in preliminary surveys and to construct maps and profiles of locations on paper, in which the imagination of the draughtsman was allowed full play. Rival companies vied with each other in planting their stakes and their bonds, but no practical good came of either.

The New York, West Shore & Chicago Railroad Company was incorporated on the 13th of July, 1870, in the State of New York, to build and operate a line of railway from the state line of New Jersey on the Hudson to a point on the Niagara River. The New York & Fort Lee Railroad Company, of New Jersey, was authorized to build a railroad from Hoboken to the state line of New York, but transferred its rights and franchises by lease dated July 26, 1871, to the New York, West Shore & Chicago Railroad, so that the latter corporation became empowered to build and operate a railroad from Hoboken to Buffalo. John M. Courtenay was the president of the company and Gen. Charles B. Stuart engineer-in-chief. Both these gentlemen are now deceased. The plan of the route in its general location and in the character of its grades was due to the eminent engineering ability of Gen. Stuart, who was the originator and chief promoter of the scheme.

During the year 1872 ten corps of engineers, numbering twelve men each, were placed in the field to locate the line between Hoboken and Buffalo. On the 1st of February of that year the writer was appointed Chief Engineer of the Seventh Corps, and assigned to the most difficult portion of the line, the Highlands of the Hudson, including Fort Montgomery, Cozzen's Rock, West Point and Storm King and extending to Blue Point, nearly opposite Poughkeepsie.

The prominent points of the Highlands rise directly from water 80 to 100 feet deep, at an angle of about 67 degrees to the horizon, great masses of granite, towering to heights varying from 250 to 1,400 feet above tide. The indentations of the shore present, in some instances, rock no less precipitous, though here the water was comparatively shallow at the shore, the bottom consisting of a thin layer of soft black silt upon a hard clay which descended at a slope of about 4 or 5 to 1 to the channel bank of the river, where it went off suddenly into deep water at a slope of 30 or 40 degrees.

It was the fixed policy of Gen. Stuart to avoid the use of tunnels, excepting at West Point; hence the location resulted in side cuttings on

bluff points, wide enough to accommodate the entire roadbed, and in embankments across the bays, sufficiently removed from the channel bank, as was believed, to prevent slipping. At the same time it was the aim of the engineer to equalize the cuts and fills as far as might be with curves limited to four degrees, and a grade perfectly level, 12 feet above low-water mark. The rise of the tide is about 4 feet.

At the outset a preliminary survey was made with extraordinary care, by which were determined all the features of the shore, and cross sections were taken above and below water. The inaccessible points were passed on the ice, which was then firm, and the slope angle observed. As the location could only be studied on paper, the preliminary survey was plotted at 100 feet to the inch, and the contours drawn at every 5 feet (sometimes oftener) above and below low-water mark. After the location had been projected on these maps a set of notes for the field was made from them, noting all crossings of the preliminary and located lines, and the offsets from one to the other at every instrumental point. By means of these notes the location was placed on the ground after the ice had disappeared; not continuously, of course, but in patches at accessible places, depending for continuity on the accuracy of the preliminary. As there was seldom earth enough on the rock to hold a stake, the stations and other points were secured by short plugs of iron let into holes drilled in the rock and projecting half an inch or more. Long stakes were used to mark the stations in the water. The line was then leveled, sounded and cross-sectioned, and a profile made of both the centre line and side lines of the proposed roadbed. This profile had a horizontal scale of 100 feet to an inch. An estimate was finally prepared, and this, together with reduced maps and profiles of about 30 miles, were submitted by the 1st of July, 1872, five months from the start, one month, however, having been employed by the seventh corps in locating through Erie County and running a preliminary through Ontario and Seneca counties. Further study suggested some changes in the line, which were made chiefly to throw it more inshore where it seemed to be too near the channel bank.

The U. S. Military Reservation, including the post of West Point, extends along the river about 2½ miles from a point a little below West Point, Landing northerly to a point near "Cro' Nest," opposite the village of Cold Spring. No right of way, in the ordinary sense of that term, could be obtained across this reservation, but by an act of Congress passed February 16, 1869, the then existing "West Shore & Hudson River Railroad Company" was authorized to pass through these lands by consent of the Secretary of War under such conditions as he might see fit to impose. When this old company was absorbed by the New York, West Shore & Chicago Railroad Company, all its rights and franchises came into the possession of the latter, including the right to cross the reservation. The Secretary of War in 1872 demanded that West Point should be passed by a tunnel, to avoid disturbing the picturesque beauty and seclusion of the shore at this historic spot. It is probable, however, that the tunnel would have been driven in any case, as the alignment is thereby much improved.

The company completed its location and its land maps in 1872, ac-

quired some right of way, and purchased some terminal property; but no construction was accomplished beyond excavating the approaches to the tunnel, and doing a little ordinary grading at three or four points where it seemed advisable to secure the located line against rival companies. Notwithstanding the fact that the company began the year with some $3.000,000 in its treasury, the funds seemed to be nearly exhausted by the close of the year. The remnant of the engineer corps was discharged January 1, 1873, with one or two exceptions, and the company became bankrupt soon after, even the office furniture being seized and sold for debt. The panic which followed in September cast its black pall over the corpse, and the project seemed to be, for many years, beyond the hope of resurrection.

At length, in 1880, after many stormy meetings of the bondholders of this and prior companies, a new organization was effected, which is the present New York, West Shore & Buffalo Railroad Company. An arrangement to build that part of the river line lying between Haverstraw and Cornwall was made with the New York, Ontario & Western Railroad Company as a part of its through line to New York City. Walter Katté, Esq., was chief engineer of this company. The writer was made division engineer in charge of this work, and of the branch from Cornwall to Middletown, for the Ontario company; also of the river line from Cornwall north to the Ulster County line, for the North River Construction Company. Having carefully preserved all the original maps, profiles, sections and field notes of his former location along the river, he was now able to bring these at once into service, and thus to prepare the line for the contractors' operations very much sooner than would otherwise have been possible. The iron plugs of the former survey were readily found and identified, having stood guard over the line for eight years. The old location was generally adopted on the river division, except that some of the side cuttings were made heavier, and the fills lighter. The policy of avoiding tunnel work was adhered to.

The plan of construction contemplated placing the rock from the cuts in the fills in the usual manner, but this could not always be done. Some side cuts were so long and so deep that time could not be spared to excavate from the ends only, so that when a foothold had been secured by blasting a path along the upper limit of the cutting, the level ledge so formed was worked down to grade, quarry fashion, the rock being blown directly into the river by hundreds and thousands of yards. Even where it was desired to save the material, great difficulty was experienced in preventing the rock from being thrown overboard by the force of the blast, so narrow was the roadbed compared with the depth of the cuts. It was found necessary to appoint inspectors of blasting to prevent the contractors from making a general waste. From Dunderberg to Storm King there was no cutting in any material but solid rock worth mentioning, except at Target Hill, and no place where a borrow pit could be made except at one point known as the "Slide."

The clay bottom of the river bays proved itself in some instances a treacherous foundation for the embankments. Apparently hard and firm, it would support the rock filling for some weeks or even months,

and then in some places it would suddenly slide upon the smooth bed-rock, carrying the embankment with it down and out to the river channel, leaving the water on the located line considerably deeper than before. Sometimes a second bank built upon the rock, and having the first bank for a support at the toe, would be permanent; in other cases bank after bank would slip away, leaving no recourse but to change the line to avoid the insatiable holes. These changes of line involved over 80,000 cubic yards additional rock cutting and a considerable amount of sharper curvature. There was one such hole on the south side of Storm King apparently of so small extent in the beginning that it was thought there would be a superabundance of rock in the cut to fill it; but persistent dumping for six months failed to make any embankment show above the water, and the line was thrown a little deeper into the mountain, and a four-degree curve replaced by a ten before the roadbed could be formed.

At Cranston's is a pocket in the rocky shore that no amount of material would fill. It was finally bridged by two spans, one of 135 ft. and one of 89 feet. In place of a pier between the spans, a heavy iron girder projects from the cliff in the form of a bracket bolted to the rock, a drawing and description of which is published in the *Railroad Gazette* of May 11, 1883. The writer lays no claim to this design. In this bridge the west truss is over the shore while the east truss is over water 80 or 100 feet deep. There is a similar case at Fort Montgomery, where a little bay extending two hundred feet along shore lies between two rock-cuts, one of them very heavy. The centre line was on shore, but the rock would not fill the half roadway over the water. A dock builder proposed to build a crib here and anchor it to the shore. He did so; and when his work was nearly completed at a cost of some $10,000, the structure took French leave, and was afterward discovered to have lodged 500 feet from shore in water 100 feet deep, where it now rests in company with the great chain of revolutionary fame. The gap is now spanned by a handsome iron bridge in one span.

Near Buttermilk Falls a rock-cut had been taken down to grade, the entire road-bed resting on the cut, when the half-bed next the river slipped down and disappeared. Of course, the only remedy was to work the cut over again, beginning at the top, 75 feet above the grade, and taking off about 16 feet. At Storm King the cutting was 90 feet deep on the upper side, at Hampton 125 feet deep, all in the solid rock. Yet the greatest difficulty encountered was not so much in the cuts as in certain fills near them, as already explained.

It now seems to be pretty well proved that the policy of adopting a surface line along such a bold and rugged shore was an unwise one. The amount of rock excavation is very much greater than would have resulted from the adoption of a line with a few short tunnels, so much so as to overbalance the increased cost of tunnel work per cubic yard. A tunnel line would have less curvature than the original location, and this advantage is still more apparent when compared with the present line distorted as it now is, under the exigencies of the case in a number of places, by sharp and sometimes reversed curves. A tunnel line would have voided all the difficulties of slipping embankments, being so much more

in shore, while the tunnel material would have made such banks as were required without waste. As all the tunnels would have been in apparently solid, self-sustaining rock, the contingency of delay and increased expense could not have been so great as in placing heavy embankments on the treacherous river bottom, and the line might have been earlier opened to traffic. Added to these advantages is the no mean one of exemption from the danger to passing trains of snow slides and falling rocks from the mountainous heights.

Before work could be resumed at West Point it was necessary to obtain further legislation from Congress. A new bill was passed empowering a Commission of West Point officers to prepare, subject to the approval of the Secretary of War, the conditions upon which permission would be granted the company to begin operations on the reservation. The Commission took good care that the Government should not be a loser in the transaction, and greatly increased the conditions over those imposed in 1872. The company, having no option in the matter, complied with them all. Among these may be mentioned the construction of a new pier at the steamboat landing, as the old one was going to decay; the providing of an extensive system of sewers for the houses and roads on the north side of the post; the filling up to grade of the entire bay north of the post, included between the railroad and shore; the preserving of the target ground for the "seacoast battery" by diverting the line of the railroad from the shore of Target Hill to a ravine behind it, from which, in order to gain the river front again, it was necessary to make a cutting through the spur 140 feet deep and 450 feet wide on top, containing 435,000 cubic yards of gravel and hardpan, and, finally, the building of an astronomical observatory near Fort Putnam at a cost of not less than $50,000. The material was taken from Target Hill by steam shovels, and hauled by trains from each end of the cut to fill the bay as required.

The work of constructing the line through the Highlands was begun in June, 1880, and was about completed in December, 1882, covering a period of two years and five months.

The cost for graduation and masonry was about as follows:

On the section from Fort Montgomery to West Point, 4.52 miles, $290,000, or $64,400 per mile; on the section from the U. S. Reservation to Cornwall, 3.34 miles, $255,000, or $76,500 per mile; on the U. S. Reservation, 2¼ miles (including the West Point Tunnel, 1 mile), $750,000, or say $333,300 per mile.

Thus 10.11 consecutive miles cost for graduation and masonry alone about $1,295,000. To this sum must be added the cost of an exceedingly expensive right of way, and of tracklaying and bridging, besides all the incidental expenses of a great and difficult work.

The first train ran from Middletown to West Point on January 8, 1883. The first regular passenger train ran through from Jersey City to Newburgh on June 4, 1883, and this portion of the road was declared open for business on that day.

THE QUANTITY OF AIR REQUIRED IN THE VENTILATION OF BUILDINGS.

By R. F. Hartford, Member of the Western Society of Engineers.

[Read August 4, 1885.]

The following is submitted as addendum to the interesting paper on "Ventilation of Stables," recently presented by Mr. A. W. Wright, Member of this Society.

The authorities consulted have been Pettenkofer, De Chaumont, Parkes and others. From these we learn that a man *at rest* exhales for each pound of his weight 0.00424 cubic feet of CO_2 per hour. Under the same conditions he exhales 0.1189 cubic feet of air.

If n = number of miles a man may walk in one hour (or its equivalent in other work), then

CO_2 per pound of weight per hour

$$= 0.00424 + 0.00211\, n, \qquad (1)$$

and air exhaled per pound of weight per hour

$$= 0.1189 + 0.0591\, n. \qquad (2)$$

In the paper by Mr. Wright it is stated, on the authority of the Boston *Journal of Chemistry*, that "a horse or cow is said to have six times the breathing capacity of a man." This is the allowance commonly made in the ventilation of mines in Europe, where the animals used are about six times the weight of the average miner. If this allowance be a correct one, and experience indicates that it is, we may assume that the larger domestic animals have the same breathing capacity as man per pound of weight.

Now let

V = cubic feet of air required in a given time,

T = time in hours,

W = weight of man or animal in pounds,

x = allowable excess of CO_2 above that in normal atmosphere.

Then

$$V = \frac{(0.00424 + 0.00211\, n)\, W\, T}{x}. \qquad (3)$$

The best authorities have agreed that 6 parts of CO_2 in 1,000 parts of air should be the maximum limit with good ventilation. The normal condition is about 4 parts of CO_2 in 10,000 parts of atmosphere, making for all practical purposes

$$x = 0.0002. \qquad (4)$$

The average weight of a car horse may be taken at 1,100 pounds $= W$.

If it be assumed that in a stable a horse does work equivalent to $n = \frac{1}{4}$, the formula for stable ventilation becomes

$$V = 26235\, T, \text{ or} \qquad (5)$$

V = 437.25 cubic feet of air per minute.

If the horse be regarded as at rest, $n = 0$ and

V = 388.7 cubic feet of air per minute.

Formula (3) is of general applicability.

I am aware that my results look large, but I believe they are no larger

than good ventilation requires, if the ventilating apparatus alone is relied upon to furnish the fresh air. That unknown quantity which may pass through cracks, etc., is not considered.

Of course, the results change with the choice of a different value of x. Some authorities say the limit of CO_2, in good respirable air, may be 10 parts in 10,000 parts, making $x = 0.0006$, and $V = 7773$ cubic feet of air per hour as necessary for one horse (about 26 cubic feet per minute more than Mr. Wright gives). But if the experiments of Drs. Angus Smith, Parkes, Pettenkofer and De Chaumont have any value this is much too low for *good* ventilation.

AN AMERICAN ENGINEERING LITERATURE SOCIETY.

By J. A. L. Waddell, Member of the Western Society of Engineers.

[Read July 7, 1885.]

In a paper upon "A Proposed Review of Engineering Literature," presented not long ago to the Engineers' Club of Philadelphia, after pointing out some of the deficiencies of technical works and suggesting that they need improvement, the writer states that "the work to be accomplished can be divided into two parts; first the collection and valuation of what has been already printed, and second the improvement of future technical works." That paper dealt with the first division; this will treat of the second.

Not only is engineering literature far behind the practice of the day, but many of the technical works in use are of an unsatisfactory character; and one of the principal reasons why engineering education in technical schools is not of a more practical nature is the scarcity of really practical engineering books. To suggest a means of improving the style and widening the scope of technical literature is the object of this paper.

As in any other great undertaking, success can be achieved only by united action; hence, as may be anticipated from the heading of this article, the writer would advocate the formation of a society, the members of which should consist not only of those who have written or intend to write technical works, but also of other engineers of high standing in the various branches of the profession, whose opinion as to what books are needed and how they are to be prepared would be authoritative; and who could act as revisers of books written by the other members. These two classes of members might be termed active and honorary.

The organization of such a society would not be a difficult undertaking. A few of those especially interested might send letters to all the authors of engineering books who reside in North America, asking them to meet at a certain time and place for the purpose of organizing a society whose object would be as explained, at the same time publishing in the technical journals a similar letter, asking all engineers who have any intention of ever writing technical books to send in their names to a certain address as candidates for election. At the first meeting a temporary set of rules should be drawn up, and the candidates whose names have been received voted upon. Those elected should be so

notified, and requested to attend another meeting at a certain date and place. At this second meeting there should be nominated and voted upon for honorary membership, engineers of acknowledged ability and experience. At a third meeting of both classes of members a constitution should be prepared, committees appointed and business matters arranged.

The method of accomplishing the society's object, viz., the improvement of engineering literature, might be as follows:

1st, The suggestion of subjects for books needed

2d. The appointment by a committee of a writer for each subject, on which the society as a body deems it expedient that a book be written.

3d. The appointment of a reviser or revisers of each book.

4th. A discussion by the society as to what each book should contain and how the subject should be treated, the author to be in no way bound (except in one particular to be mentioned later) to adopt any conclusions arrived at in said discussion, but accepting them merely as suggestions.

5th. The making of such arrangements by a committee that the author of each work can obtain all the data and information which he needs, from the most competent and reliable sources.

6th. The establishing of a feeling of good-fellowship among the members, by reason of which one member will have no hesitation in asking another for any assistance that he may require in the preparation of a book.

7th. An arrangement with a good publishing firm to print and sell at the risk of the firm all books published under the auspices of the society, a certain percentage of the gross receipts being turned over to the author, and another, but smaller percentage, to the society.

8th. The indorsement by the society of each book on the cover and title page.

The effect of this indorsement would be to almost guarantee to the publishers a profitable sale of the book, so that, the risk being small, the author's percentage of the receipts should be large.

In preparing rules and regulations for the society, care should be taken that the individual liberty of action of writers should be interfered with as little as possible. Any member should be free to publish any book he chooses without consulting the society, provided he does not sign himself therein as a member of the society, or cause any inference to be drawn that the book was published with the consent of the society. The number of books so published would be very small, for the advantages of the indorsement of the society should be decidedly great. No member need feel any obligation to serve as either author or reviser because asked to do so by the committee.

If two or more persons have been intending to write on the same subject, they may conclude to work together upon the same book, or one or more may withdraw. In any such case, if the parties cannot come to an agreement among themselves, the society should conclude not to publish any work on the subject until the books of all the disputants are either issued or abandoned, or until after the lapse of a reasonable time for the preparation and publication of such books.

The fact of a subject having been once written upon by an authorized

member of the society should not preclude its being written upon again by another member, provided that the latter shows good reason for a further and more detailed treatment of the subject; nevertheless the society should exercise a good deal of caution in such a case.

Revisers should receive payment for their services, the amount in each case being determined by a standing committee.

If a disagreement arise between a reviser and a writer, the matter could be referred to a committee specially, or the reviser could insert his objections in a foot note or foot notes, or he could refuse to act as reviser, thereby forfeiting a portion of his fee. A book reported upon by the reviser as fundamentally incorrect, if not withdrawn by the author, could be referred to a committee, who would decide as to whether the book be worthy of publication or not. If rejected, the author should be at liberty to publish it on his own responsibility, and such a course of action need not necessitate his resigning from the society.

The society should have the right to determine the contents of each book to this extent, that one author should not interfere with the province of another or incorporate in his treatise more than a mere summary of a book published under the auspices of the society, unless the author of said book consent to a more extended quotation. This restriction would not be a severe one, as it would be found much more satisfactory to refer to another work which gives a good treatment of the point considered, than to run the risk of giving one's book the reputation of being a mere compilation, unless the aim of the author were to prepare only a compilation.

The dues should be paid by active members only; and they need not be large, for the society's percentage of receipts should be sufficient to pay the revisers' fees, leaving only the running expenses to be met by the dues.

Meetings of the society should be at least semi-annual; they might take place immediately after the annual meeting and the annual convention of the American Society of Civil Engineers. A reporter should be employed to take down the discussions at meetings, and the notes should be printed for circulation among members and others interested. A summary of the notes might be printed in the technical journals, so as to invite discussion from non-members.

The books which are specially needed by the profession may be divided into three classes; first, those to treat of large divisions of engineering; second, those to treat of subdivisions of the same; and third, monographs of engineering structures completed or abandoned. Of the first class there are a good many books already in the market. The objection to most of them is that they seem to contain nearly everything except the one thing sought. There are some, however, which appear to cover the whole, or nearly the whole, ground in an adequate and systematic manner. Of the second class there are not many good examples, although some of the later books of this kind show progress in the right direction. Of the third kind, too, there are only a few specimens by American engineers, but these few are excellent, and it is to be hoped that the example set by their authors will be followed by other eminent engineers.

As examples of what books are needed, the writer would suggest the

following as titles : Foundations, Castings, Mine Surveying, Sewerage, Surveying Instruments, City Engineering, Pile Driving, Railroad Bridge Designing, Water-Works Construction, The Designing of Ships, Estimates, Dredging Machines, The Removal of Earth, Masonry, The Use of Hydraulic Cement, Timber Trestles, Military Engineering, Railroad Management, Pumps, Braced Piers, Hydraulics of American Rivers, Canal Surveying and Construction, American Harbors, Torpedoes and Torpedo Boats, The Use of Steel for Bridges, The Designing of Masonry Arches, and Combination Bridges.

In the preparation of most engineering books, it is the writer's opinion that it is well to avoid all unnecessary use of mathematics ; but, if mathematical discussions and proofs be essential, they should be confined to appendices.

The idea entertained by so many, that a book of which the larger part is not original reflects discredit upon the author, is entirely erroneous. On the contrary, a striving after originality is liable to cause the advocating of impracticable schemes. Very useful treatises may be mere compilations, or may be based upon the unwritten experience of other engineers than the author. Technical works should treat of bad practice as well as of good, pointing out errors into which an inexperienced engineer is liable to fall ; in fact, many a useful treatise might be written upon engineering work that has proved a complete failure.

The amount of technical writing required at present and in the near future is great enough to employ all the spare time of all those who have the necessary ability and experience, so no writer need fear that in joining such a society as the one proposed he will lose the opportunity of presenting to the public the results of past labor.

The advantages to be gained by the formation of the proposed society are, in short, these : for authors, the suggestion of new ideas by comparison of notes, the obtaining of material and data through the influence of the society and its members, the indorsement of their books by the society, a satisfactory and fixed arrangement with publishers, and the avoidance of errors, which without the assistance of a second and competent party is extremely difficult : and for the engineering profession, the acquisition of a number of much-needed books, which may be regarded as standard and reliable, and which will bring engineering literature as nearly as it is possible abreast of engineering practice.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

AUGUST 18, 1885 :—The 214th meeting was held in the Society's Hall, 15 Washington street, at 4 P. M., Mr. A. Comstock in the chair.

In the absence of the Secretary, Mr. Liljencrantz was appointed to act as Secretary *pro tem.*

The minutes of the preceding meeting were read and approved.

Applications for Membership were received from Abraham Gottlieb, C. E., Chicago ; Barnabas Schreiner, City Engineer, Des Moines, Iowa ; Gustave Lauritz Clausen, C. E., Hyde Park, Ill., and Henry R. Chichester, of Chicago.

Mr. A. W. Wright, for the Committee on Railroads and Transportation, submitted a communication in reply to Mr. T. J. Nichols' questions relating to the comparative economy and capacity of standard and narrow-gauge railroads, and to the most economical section and weight of steel rails under certain conditions. Referred to the Secretary.

Mr. Wright moved that the qualifications, etc., for Membership, be printed on the backs of the blanks for application. Carried.

The Librarian called attention to the need of additional facilities for the proper care of the library, and asked for authority to order a new book-case, submitting design and estimate of cost for the same. On motion it was referred to the Secretary and Librarian, with power to act. Adjourned.

G. A. M. LILJENCRANTZ, Secretary *pro tem.*

SEPTEMBER 1, 1885.—The 215th meeting was held in the Society's Hall, at 4 P. M. Mr. Wright was called to the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a Member was presented from Mr. John Watson Alvord, Town Engineer, Lake View, Ill., indorsed by Messrs. Cole, Nichol and Wright.

The Secretary read a communication from Mr. C. P. Matlack, City Engineer, San Antonio Texas, asking information as to the best method of disposing of house garbage in inland cities, the City of San Antonio proposing to erect a "crematory."

The Secretary read a paper by Mr. Samuel McElroy, "The Water-Power at Niagara Falls."

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

Members are requested to send to the Secretary their views on the question asked by Mr. Matlack.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

JULY 14, 1885 :—Regular meeting held, President Halloway in the chair. Minutes of last meeting read and approved.

The Committee appointed to consider the relation between military and civil engineers upon government works (other than military) made a brief report, and asked that the following resolution be adopted :

Resolved, That the Committee on the Relation between Military and Civil En-

gineers on Government Works (other than military) be authorized to invite the several engineering societies of the country to appoint similar committees, briefly stating the object of the movement, and, in order to obtain united action, to also invite each of these committees to send a representative to form a central committee, which shall meet in this city to fully discuss the question, and decide upon some definite plan of action upon which all, if possible, may unite; said action to be reported back to the several societies for their approval.

(Signed) W. T. BLUNT, Secretary of Committee.
J. EISENMANN, Chairman.

Resolution adopted.

By various resolutions, it was decided to hold a picnic at Silver Lake, July 25.

The President appointed the following committee to arrange for the picnic: Charles Latimer, M. E. Rawson, A. Swasey, E. H. Jones and Hosea Paul; the President to act as Chairman of the Committee.

Mr. Theodore Rosenberg then read a paper, entitled "Fire-Proof Buildings," after which the following resolution was presented:

Resolved, That a committee of three be appointed to report upon the advisability of a City Building Bureau.

The resolution, after being amended so as to have the Committee on Architecture make such report, was adopted.

A vote of thanks was tendered to Mr. Rosenberg for his paper.

[*Adjourned.*] M. W. KINGSLEY, Rec. Sec.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. IV. October, 1885. No. 12.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

INDEX DEPARTMENT.

ANNUAL SUMMARY.

It is proposed to furnish, in this department, as complete an Index as may be of current engineering literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value. It is printed in the monthly issues of the JOURNAL, *on but one side of the paper, so that the titles may be cut out and pasted on cards or in a book, and is here collected with additional titles and many cross-references.*

All readers of the JOURNAL *are requested to aid in making the Index as complete as possible. All notices for this department, and all matter to be here indexed, should be sent to* J. B. JOHNSON, *Manager Index Department, Washington University, St. Louis, Mo.*

A

Aerial Navigation. A short sketch of its history and a description of a new form of motor for an air ship. *Am. Engineer*, May 22, 1885.

——. By Dr. William Pole, F. R. S. An extended discussion of the subject, in a paper before the *Inst. of Civ. Engrs.*, Vol. LXVII. Also, by same author, "Some Further Data on Aërial Navigation." *Am. Engr.*, Aug. 6, 1885. The former article is one of the most valuable that has ever appeared.

——, *Recent Improvements in.* By Prof. W. Le Conte Stevens. An historical article, giving the recent improvements made in France up to 1885. Illustrated. *Pop. Sc. Monthly*, July. 1885.

——. *The present state of*, giving most modern devices, with mathematical discussion of principles, by M. De Bruignac. *Proceedings of Society of Civil Engineers*, Paris, October, 1884.

Air, *Flowing in Pipes, Coefficient of Friction of.* By. Prof. W. C. Unwin, M. I. C. E.

——, *Purity of. See* Atmosphere.

Tabular values derived from experiments. *Eng. News*, July 11, 1885.

Alaska, *The Resources of.* By Fred'k Schwatka. With especial reference to timber and minerals. From *Bradstreet's* in *Sc. Am. Suppl.*, July 4, 1885. Also *Eng. and Min. Jour.*, June 27, 1885.

Alloys, *Strength of.* See Bronzes.

American Engineering Enterprise. A paper read before the Society of Engineers by Arthur Riggs *Engineer*, Maach 6, 1885.

Ammonia. See *Tar and Ammonia.*

Ampere, Ohm and Volt, *Direct Measurement of.* J. Kessler. London *Electr. Rev.*, April 11, 1885.

Anchor Gear. A description of Baxter's system for working cables, as applied to car o and passenger steamers. *Engineering*, Feb. 20, 1885.

Anthracite Coal Fields of Pennsylvania, a description of. By Charles A. Ashburner, of the Geol. Survey of Penn. A 30-page article, giving the Geography, History, Topography, Structural Geology, Stratigraphical Geology of the region, together with the Composition and Origin of this Coal, methods of mining, and production statistics. Proceedings of Engrs'. Club of Philadelphia, Vol. IV., No. 3.

Appliances designed and used in connection with the Tennessee River Improvement, viz.: *Derrick Winch* that lowers rapidly; *Derrick Grapple*, *Portable Drill*, for use on iron lock gates; *Iron Canal Lock Gates*, with solid and with trussed girders: *Balanced Wickets* designed to prevent leaking; *Inexpensive Switching Locomotive*; *Tests of Wooden Beams*, to show effects of notching and mortising, with important results; *Apparatus for testing the Strength of Explosives*, being simple and inexpensive. All these described and illustrated. Rep. Chf. of Engrs., U. S. A., 1883, Vol. II., p. 1483.

Aqueduct, *The New Croton.* Specifications for Section 9, with many cross-sections shown. *Engineering News*, March 7, 1885, *et seq.* *See* also Croton.

——. The various forms of the new Croton aqueduct for different materials traversed. Seven illustrations. *Sanitary Engineer*, May 21, 1885.

Aqueduct Bridge *Across the Potomac at Georgetown, D. C.* Report of S. T. Abert, U. S. C. E., Ex. Doc. No. 156, House of Rep., 47th Congress, 1st Session; also in Ex. Doc. 169, House of Rep., 48th Congress, 1st Session.

Arch, *Elastic, Graphical Analysis of Stresses in*, after Culmann. By R. H. Graham. Illustrated. *The Engineer*, July 17, 1885.

——. *See* Conduit; also Concrete.

Arctic Geography. By Lieut. A. W. Greely, U. S. A. A brief abstract, with map, of the work of the Greely Expedition. *Science*, February 27, 1885.

Armor-Plates, *The Manufacture of Iron and Compound.* Translated from the Russian. Being a description of the methods employed by Chas. Cammell & Co. and John Brown & Co. Illustrated. *Mechanics*, Aug., 1885, *et seq.*

——. On the protective value of armor plates as proved in actual warfare. *Engineer*, May 15, 1885.

——. Results of experiments with Gruson's chilled iron armor. *Engineer*, May 8, 1885.

Artesian Wells, *Materials and Methods of Boring.* By C. W. Darley, of New South Wales. Fully illustrated. *Engineering*, June 19 and 26, 1885.

Asbestos. The methods used in the mining and manufacture of asbestos. *Engineering*, March 6, 1885.

Atmosphere. *A Test of its Purity as to Carbonic Acid.* A simple and exact quantitative test that may be applied by any one to test the fitness of air for breathing. *Abs. Proc. Inst. Civ. Engrs.*, Vol. LXXXI., p. 384.

Astronomy, *Practical.* *See* Determination, and Latitude.

Azimuth. *See* Latitude; also Determination.

B

Baldwin, Loammi. Said to be the Father of Civil Engineering in America. A biographical sketch, by Professor Vose, with portrait; published in pamphlet form by the Boston Society of Civil Engineers, 1885.

Bank Protection. Methods pursued on the Missouri River, with many cuts showing mattresses in process of construction, mattress boats, etc. Rep. Chf. of Engrs., 1883, V. II., p. 1297. *See* also Shore.

Base-Line Apparatus. A new design, by the U. S. Coast Survey, consisting of a compensating apparatus, five metres long, composed of steel and zinc bars. Description of apparatus, comparisons and method of measuring the base. Report U. S. C. and G. Survey, 1882.

Batteries. *See* Electric, Secondary and Storage.

Bessemer Steel Ingots, the Segregation of Impurities in, on cooling. By B. W. Cheever. *Trans. Am. Inst. Min. Engrs.*, V. XII., and *Jour. Iron and Steel Inst.*, 1881.

Blast-Holes, Tamping with Plaster of Paris. By F. Firmstone, *Trans. Am. Inst. Min. Engrs.*, Vol. XII.

Blasting *of rock under water.* Methods used on Welland Canal at Port Colborn, Ont. Giant powder proving ineffectual, nitro-glycerine was used with great success. *Eng. News*, July 11, 1885. *See* also Flood Rock and Hell Gate.

on a standard method of steam boiler trials. *Sanitary Engineer*, June 18, 1885. Also *American Engineer*, Nov. 14, 1884.

——. *Standard Methods of Making Trials.* Being the Report of the Committee of the Am. Soc. Mech. Engrs., consisting of Messrs. Kent, Hoadley, Thurston, Emery and Porter. Containing a Code of Rules and methods of treating the several problems involved. Also form of final report. *Van Nos. Eng. Mag.*, March. 1885.

——. Many short topical articles by the different members of the committee which was appointed by the American Society of Mechanical Engineers to report on the subject. These articles cover the whole ground of boiler trials for various purposes, giving many practical hints and precautionany measures. *Mechanics*, May and June, 1885.

Bore-Hole Testing Appliances, for giving a complete survey of a bore-hole, so that its exact position at any depth may be accurately determined. Designed by E. F. Macgeorge, of England. A scientific, simple and efficient device. *Engineering*, March 13, *et seq.*, 1885.

Boston, *Drainage of*. See Drainage.

Bower-Barff Process, *Treated Historically and Analytically*, from the Proceedings of the Inst. of Civil Engrs., published in *Iron*, Nov. 28, 1884.

Bow Girders. *Trussed Arches*, hinged at crown and springing, maximum strains in. By Emmerich A. Werner. Graphically and analytically treated. *Van Nostrand* V. XXXI, p. 320 (Oct., 1884).

Brakes, *Friction, some new forms of*, from a new French work on steam engines. Several different forms given with cuts, in *Mechanics*, New York, March, 1885.

——, *Train.* Discussion of methods determining their efficiency, and its ultimate practical limit; with tables to facilitate computations; deduced from experiments on the North British Railway. Editorials in *Railroad Gazette*, May 15, 22 and 29, 1885.

Breakwater at New Haven, Eng. An account of this structure, now building. Foundations composed of concrete, laid in sacks of 100 tons each. Concrete mixer shown. *Engineering*, July 3, 1885.

Brick Masonry, *Crushing Strength of*, Experiments on. Abstracts of Papers, 1885. (Inst. C. E.).

Brick Tests *for Hoosac Tunnel*, as to absorption and porosity. *Jour. Assoc. Eng. Soc.*, Vol. I., p. 143.

Bridge over the Elbe at Hamburg and at Harburg. Built 1869–72. Spans of about 325 feet, of "fish-belly" form, built of wrought iron; the upper chord consists in itself of two chords and panel bracing, as does likewise the lower chord, and the two are connected by vertical suspension rods only, these suspension rods holding up the track construction. The constructive analysis of the bridge makes it an arched bridge, with parallel chords and panel bracing, supported on towers erected on the piers, the height of the towers equal to the deflection of the stiffened suspension-bridge structure (above spoken of as the lower chord of the "fish-belly" bridge), and whose sole office is to neutralize the thrust of the arch. The bridge platform, or track construction, is tangent to this double lower chord, and is supported from the arch by suspension members. A comparison of the weight of this bridge with others of like span and strain on the materials of construction, shows it to be a favorable form of bridge-truss, as far as own weights are concerned. *Zeitschrift f. Bauwesen.* 1875–79.

——, *The Blaauw Krantz.* A third paper, with many illustrations, showing it in process of erection. Details and strain sheet. *The Engineer*, April 17, 1885.

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——, *Highway. Three-Hinged Iron Trussed Arch* at Clermont, Ia., of 200 feet span. Illustrated. *Jour. Assoc. Eng. Soc.*, Vol. III., p. 24.

——, *Mountain Creek, on the Can. Pac. Ry.* A wooden Howe truss on timber piers 140 feet high. Total length, 1,071 feet. Sustains a 10-degree curve on a 100-foot grade. Illustrated. *Engr. News*, Sept. 26, 1885.

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C

Cable Towing. A theoretical investigation by J. B. Johnson on the relative amounts of work performed when propelling the same boat at different speeds, with or against currents of different velocities, by cable and by paddle-wheel or screw. *Van Nos. Eng. Mag.*, Vol. XXIII., p. 369.

Cable Tramway at Highgate Hill, London. The peculiar features described of this, the first cable road in Europe, opened 1884, by W. N. Colam, before the Soc. of Engrs *Van. Nos. Eng. Mag.*, Aug., 1885.

Caissons. *Cribs and Coffer Dams* used on the foundations of the new Havre de Grace bridge on the B. & O. Ry. By Col. Wm. M. Pattyn, engineer in charge. This work is under contract by Gen. Sooysmith & Son, and the rate of progress made has been remarkable. Plans, elevations and sections given of the caissons. First article in *Engineering News* of Feb. 7, 1885.

—— *of the Forth Bridge.* A full-page cut in perspective, also sectional illustrations. *The Engineer*, Feb. 6, 1885; also *Engineering*, same date.

——, *with lateral opening against a rough masonry wall.* Descriptions of how the joint was made by means of tarpaulin, to be readily set and removed. *Engineering*, June 12, 1885; also *Iron Age*, July 2, 1885.

Calculating Instrument, or Cylindrical Slide Rule. a pamphlet of 70 pages, by Edwin Thatcher, describing a patent device for treating numbers to four significant figures, with rules for its use. Van Nostrand, New York.

Calculating Machine. *Edmondson's.* Described and cut given in *Engineering* and *Iron Age*, July 2, 1885.

Calorimeter, a new form. By Geo. H. Barnes. Apparently very good. *Am. Engr.*, Oct. 31, 1884.

Canal, Erie, *On the Radical Enlargement of the*, to permit the lake boats to pass directly to New York. By E. Sweet, with discussion by Corthell, North, Pope, Poe Drake, Boller, Walker, Chesbrough, Evans, Clarke, Edwards, Merrill, Van Buren, Henry, Chanute, Herschel, Cooper, Collingwood, and others. The proposition is to increase the depth to 18 feet, width to 100 feet on the bottom, length of locks to 450 feet, and make Lake Erie the summit. Discussion brought out a mass of statistics and opinion. Estimate of cost varies from $125,000,000 to $240,000,000. *Transactions Am. Soc. C. E.*, February and March, 1885.

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——. *Inclined Plane to serve instead of Locks.* The boat floated in water on moving trucks running on a railway. Illustrated. From the French. *Sc. Am. Suppl.*, July 4, 1885 *See* Inclined Plane.

——. *North Sea Canal of Holland.* An official report by Gen. J. G. Barnard to the Chief of Engineers, U. S. A. A quarto of 80 pp. and 11 plates. Includes also the improvement of navigation from Rotterdam to the sea. *Prof. Papers Corps of Engrs., U. S. Army, No. 22.*

——. *The Same.* Open tide-level canal proposed instead of the Amsterdam North Sea Canal, which has locks. Argument that the most desirable way to increase the commerce of Amsterdam would be by changing the present canal with locks to an open sea-level canal. Abstracts of papers. Inst. Civ. Engrs., 1885.

——, *Panama Ship*, being reports to the Secretary of the Navy of Rear-Admiral G. H. Cooper. U. S. N., and of Lieut. R. P. Rodgers, U. S. N., with numerous illustrations, including thirty-three elegant phototypes (full page) from photographs taken in January, 1884; also maps, colored profiles, etc. An exceedingly valuable report, Senate Ex. Doc. 123, 48th Congr., 1st Session.

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—— *Sault Ste. Marie.* A set of 13 drawings, 18 in. × 23 in., together with a description, and 12 photographs, showing details of construction, stages of progress, sections, plans, etc. A most valuable set of plates issued by the *Engr. Dept. of U. S. Army.* Apply to Chief of Engrs. U. S. A., Washington, D. C., or to Mem. Congr.

——, *Suez.* A history and description from 1869 to 1884. Illustrated, 160 pp Prepared under orders of the Bureau of Navigation, Navy Dept., by Prof. J. E. Nourse, U. S. N., and issued as Senate Ex. Doc. No. 198, 48th Congr., 1st Session.

Lowell, Mass., at New York City and at Johnstown, Pa. *Tr. Am. Soc. C. E.*, April, 1885, and *Engr. News*, July 11 and 18, 1885.

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——. *See* Draft.

Chimney Gases, *Analysis of*, by apparatus designed by Prof. Elliott, of Columbia, Cal. Cut of instrument, methods of use and chemical formulas. *Mechanics*, Jan., 1885.

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City Statistics, *for eighty-five of the largest cities in the world.* Given in connection with the annual address of the President of the Inst. of Civ. Engrs., London. Among the items given are : Population ; no. of houses and ratable value ; length of streets and sewers ; water supply, source and amount ; rainfall ; amount of refuse and methods of removing same ; no. of police ; no. public vehicles on the streets daily ; length of tramways or horse railroads ; no. of slaughter houses and management ; method of lighting streets, and annual death rate. *Proc. Inst. Civ. Engrs.*, 1884, Vol. LXXVI.

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Coefficient *of Contraction.* Note on the determination of the coefficient of contraction of the fluid vein. By M. Ed. Collignon. Some considerations regarding the theoretical determination of the coefficient. *Annales des Ponts et Chaussées*, 1885, March, pp. 295–303.

Coast Survey Matters. An article on Political Scientists, with replies to the same, one of which is by Prof. Agassiz. *The Nation*, Aug. 20, Sept. 3, Sept. 17, and Sept. 24, 1885.

Coffer Dams. By J. J. de Kinder and E. F. Smith. Two short papers, with drawings. *Proc. Eng. Club of Phila.*, Vol. IV., No. 4.

Coffer-Dam and Crib *of the Point Pleasant Railroad Bridge, W. Va.* A coffer-dam, with puddle-wall, inclosing an inner caisson or crib, inside of which the excavation is made. Illustrated. *Engineering News*, March 14, 1885.

Coke, *Value of.* Discussion of a paper on the use of coke in blast-furnaces. Read before the Iron and Steel Institute by I. Lowthian Bell. *Engineering*, May 15, 1885.

College Mathematics. An address by Prof. H. T. Eddy before the Mathematical Section of the Am. Assoc. Adv. Sc., 1884. A vigorous protest against the traditional spirit and methods in vogue in our classical schools. Apply to the author, at Cincinnati, O., for copy.

Combination Cars. Systems in use on railroads in Belgium and in Rhenish Prussia. *Annales des Ponts et Chaussées*, 1884-2-635.

Combustion of Fuel in Furnaces by Natural and by Forced Draught. A description of a great many experiments made in England, with results and conclusions. By James Howdon. Reprinted from *Iron* in *Van Nostrand*, V. III., p. 248 (Sept. 1884).

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The Boston Society of Civil Engineers.

CONSTITUTION AND BY-LAWS,

AND

LIST OF MEMBERS.

JUNE, 1886.

SOMERVILLE JOURNAL PRINT:
1886.

ACT OF INCORPORATION.

AN ACT

To Incorporate the Boston Society of Civil Engineers.

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows :—

Section 1. George M. Dexter, Simeon Borden, William P. Parrott, their associates and successors, are hereby made a corporation by the name of "The Boston Society of Civil Engineers," for the purpose of promoting science and instruction in the department of Civil Engineering, with all the powers and privileges, and subject to all the duties, liabilities and restrictions set forth in the forty-fourth chapter of the Revised Statutes.

Section 2. The said corporation may hold real and personal estate, not exceeding in amount twenty thousand dollars, and the funds or property thereof shall not be used for any other purposes than those declared in the first section of this act.

[Approved by the Governor, April 24, 1851.]

GEORGE S. BOUTWELL.

CONSTITUTION.

PREAMBLE.

The members of the Boston Society of Civil Engineers, in accordance with their charter and for the more effectual execution of the design of their Institution, establish and ordain the following Constitution and By-Laws for the government of said society :—

Article I.

The objects of this society are, the professional improvement of its members, the encouragement of social intercourse among engineers and men of practical science, and the advancement of civil engineering ; and for the promotion of these objects stated meetings of the society shall be held, and a library formed for the use of its members.

Article II.

Civil, Geological, Mining and Mechanical Engineers, and other persons interested in the advancement of engineering, shall be eligible as members.

Article III.

The government of the society shall consist of a President, Vice-President, Secretary, Treasurer and Librarian, who shall be elected by written ballot, by a majority of votes, at the annual meeting of the society, and who shall hold their offices until others are elected in their stead ; any vacancy, occasioned by resignation or otherwise, may be filled at the next monthly meeting after notice of said vacancy.

Article IV.

The President, and in his absence the Vice-President, shall preside at all the meetings of the society ; and in case of their absence a President *pro tempore* shall be appointed.

Article V.

The Secretary shall keep an accurate record of all the transactions of the society, notify all meetings, and issue all notices.

Article VI.

The Treasurer shall have charge of all the funds of the society, receive all assessments, and pay all bills and orders approved by the President, or in his absence by the Vice-President. He shall keep an accurate account of all receipts and expenditures, and make report of the same at the annual meeting.

Article VII.

It shall be the duty of the Librarian to take charge of the Library of the society, and to see that all books are marked with the name of the society, numbered and recorded in a catalogue. In respect to the management of the library, he shall conform to such regulations as may be prescribed by the society.

Article VIII.

The duties of the government shall be to have a general care of the affairs of the society; to provide for literary exercises at the meetings; to apply the funds in the treasury; to recommend the amount of assessments, appropriations for specific purposes, and to make a report on the affairs of the society, embracing the report of the Treasurer, at the annual meeting.

Article IX.

An Auditor shall be appointed at the annual meeting, who shall audit the accounts of the Treasurer and certify to his annual report.

Article X.

At any regular meeting of the society ten members shall constitute a quorum for the transaction of business.

Article XI.

At every meeting the Secretary shall have a list of members en-

titled to vote, which list shall not be altered during the meeting, and shall be used in voting, if demanded by one-fifth of the members present.

Article XII.

The name of any candidate for membership shall be proposed in writing by two members of the society, stating the length of his professional experience, and that they personally know him and recommend his election, all of which shall be announced by the secretary one month before he is balloted for.

Article XIII.

Any person thus nominated, who shall receive the ballots of two-thirds of those voting at any regular meeting, shall be considered duly elected, a quorum voting.

Article XIV.

Any person duly elected shall become a member on subscribing his name to the Constitution and paying ten dollars to the Treasurer, and the cost of the *Journal* from the date of admission to the date of the next annual meeting.

Article XV.

Members shall be liable for the payment of such assessments as shall be voted by the society, except that during residence fifty miles or more from Boston, any member whose dues have been fully paid, and who shall give written notice to the Secretary, may thereby be exempted from any assessment levied before the next annual meeting, and by the payment of four dollars, at or before the annual meeting, may retain his membership and be exempted from any assessment during the year following such annual meeting, or for any less period that his non-residence shall continue.

Article XVI.

Honorary members, having been nominated as required in Article XII., may be elected by a unanimous vote. They shall be subject to no fees or assessments. They may attend any meetings of the society, but shall not be entitled to vote.

Article XVII.

Any member whose dues have been fully paid may withdraw from the society by notifying the Secretary.

Article XVIII.

Any member who does not pay his assessment within eleven months after it is levied shall cease to be a member. but his debt to the society shall not thereby be discharged.

Article XIX.

A member may be expelled from the society by a two-thirds vote of those present, a quorum voting, notice having been given of such proposed expulsion by the Secretary, in writing, at least one month previous.

Article XX.

The regular meeting in March shall be the annual meeting for the election of officers and the hearing of the annual reports.

Article XXI.

No proposition which includes the society's endorsement shall be passed, except in the same manner as prescribed for amendments to the Constitution.

Article XXII.

Any amendment to the Constitution may be made by a two-thirds vote passed in its favor at each of two successive regular meetings, or by the assent, in writing, of two-thirds of the whole number of immediate members signified to the Secretary within one month preceding a regular meeting, and announced and recorded by him at that meeting. Amendments may be made to the following By-Laws, by a two-thirds vote, at any regular meeting, providing they have been proposed in writing at the previous regular meeting.

BY-LAWS.

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1. The regular meeting of the society shall be held on the evening of the third Wednesday in every month.

2. The following order of business shall be observed at all regular meetings, unless set aside by a vote of the members present:—

   1. The reading of the record of the previous meeting.
   2. Balloting for members.
   3. Business and reports of committees, or until 8 P. M.
   4. Literary exercises.
   5. Unfinished business.

3. The President may call meetings of the society when he deems it expedient, and shall be bound to do so at the written request of five members, stating the purpose of such meeting.

4. At the annual meeting any existing special committees shall expire, unless continued by a vote of the society.

5. Ten months after an assessment is levied, the Secretary shall send the following notice to any members who have not paid the same nor been exempted from payment :—

DEAR SIR :—

Your assessment levied . . . not having been received, in conformity to the By-Laws, your attention is hereby called to Article XVIII. of the Constitution, which is as follows :—

ARTICLE XVIII.

Any member who does not pay his assessment within eleven months after it is levied shall cease to be a member, but his debt to the society shall not thereby be discharged.

6. A record of all donations to the society, whether in money, books, maps, models, or other articles of value, with the names of the donors, shall be entered by the Secretary in a book provided for that purpose, to be kept at the rooms of the society.

7. Any gentleman, not a resident in Boston, may be introduced to the rooms of the society by any member, who shall inscribe his name in a book provided for that purpose, together with his own name; and the person so introduced shall be entitled to the privileges of the rooms for one month. This privilege may be renewed at the discretion of the government.

8. A book shall be kept by the Librarian in which members may enter the title of any book which they may wish to have added to the Library.

9. The records of the society shall be at all times open to any member of the society.

10. The annual report shall be signed by at least four members of the government, of whom either the President or Vice-President shall be one.

11. The Secretary, *ex officio*, shall be the society's representative on the Board of Managers of the Association of Engineering Societies.

12. The salary of the Secretary shall be one hundred dollars a year.

BOSTON SOCIETY OF CIVIL ENGINEERS.

OFFICERS

For the Year Beginning March, 1886.

President,

GEORGE L. VOSE.

Vice-President,

L. FREDERICK RICE.

Secretary,

HORACE L. EATON,

Treasurer,

HENRY MANLEY.

Librarian,

HENRY D. WOODS.

Auditor,

FRED. P. STEARNS.

SPECIAL COMMITTEES.

On Weights and Measures.

Charles H. Swan, Charles W. Kettell, Charles W. Folsom.

On the Preservation of Timber.

President George L. Vose (*ex officio*).

Ernest W. Bowditch, James B. Francis. William Watson,
Edmund K. Turner, Henry Manley, Hezekiah Bissell.

On National Public Works.

Desmon FitzGerald, William McClintock, Sidney Smith.

On Excursions.

Dexter Brackett, Alfred E. Burton, Desmond FitzGerald,
William S. Barbour, Marshall M. Tidd.

On Library.

Librarian, Henry D. Woods, and Secretary, Horace L. Eaton, (*ex officio*).

George R. Hardy, Charles H. Swan, George F. Swain.

MEETINGS.

Annual Meeting.—Third Wednesday in March.
Regular Meetings.—Third Wednesday of the month at 7.30 P. M.

Meetings held at Room 27, Boston & Albany Railroad Station, Boston.

LIST OF MEMBERS,

WITH ADDRESSES AND DATE OF ELECTION.

Members are particularly requested to inform the Secretary of any change of address.

HONORARY MEMBERS.

Blake, John H., July 3, 1848.
Retired from active business.
53 Devonshire St., Room 6, Boston, Mass.

Chesbrough, E. S., July 3, 1848.
171 La Salle St., Chicago, Ill.

Darracott, Franklin, July 3, 1848.
Vice President Nason Manufacturing Co.,
71 Beekman St., New York, N. Y.

Felton, Samuel M., Oct. 2, 1848.
President Pennsylvania Steel Company.
President Delaware Railroad, (leased to Phila., Wilmington & Baltimore R. R. Co.)
Care of Penn. Steel Co., 208 South Fourth St., Philadelphia Penn.

Haswell, Charles H., June 3, 1850.
Civil and Marine Engineer,
P. O. Box 2,961, New York, N. Y.

Parker, George A., March 22, 1852.
Consulting Engineer,
South Lancaster, Mass.

Whitwell, William S., July 3, 1848.
Engineer and Treasurer, Boston and Roxbury Mill Corporation,
68 Devonshire St., Boston, Mass.

CORRESPONDING MEMBERS.

Pike, William A., May 26, 1875.
Professor of Engineering, University of Minnesota,
University of Minnesota, Minneapolis, Minn.

ACTIVE MEMBERS.

Adams, Edward P., October 17, 1883.
Landscape Architect and Sanitary Engineer,
19 Exchange Pl., Room 14, Boston, Mass.

Allen, C. Frank, March 24, 1875.
Asst. Attorney, A. T. & S. F. R. R.,
Socorro, N. M.

Allen, William A., April 15, 1885.
Chief Engineer Maine Central Railroad Company,
Portland, Maine.

Andrews, David H., May 18, 1881.
Proprietor Boston Bridge Works,
70 Kilby St., Room 83, Boston, Mass.

Appleton, Thomas, June 8, 1874.
City Engineer, East Saginaw,
East Saginaw, Mich.

Aspinwall, Thomas, March 17, 1880.
Aspinwall & Lincoln, Civil Engineers,
7 Exchange Pl., Boston, Mass.

Barbour, William S., Oct. 19, 1881.
City Engineer, Cambridge,
City Hall, Cambridgeport, Mass.

Bement, R. B. C., November 15, 1882.
Engineer, Treasurer and Manager Charleston Water Works Co.,
Charleston, Kanawa County, West Virginia.

Bidwell, Lawson B., November 19, 1884.
Chief Engineer New York & New England Railroad,
224 Federal St., Boston, Mass.

Bissell, Hezekiah, March 20, 1883.
Master of Maintenance of Way, Eastern and Northern Division
Boston & Maine Railroad Co.,
Salem, Mass.

Blodgett, George W., June 8, 1874.
Asst. Engineer B. & A. R. R., in charge of Electrical Apparatus,
Boston & Albany Railroad, Boston, Mass.

Borden, Philip D., Jr., March 15, 1882.
City Engineer, Fall River,
P. O. Box 248, Fall River, Mass.

Bowditch Ernest W., June 8, 1874.
Landscape Gardener and Engineer,
60 Devonshire St., Boston, Mass.

Bowers, George, March 17, 1886.
Assistant Engineer, City Engineer's, Lowell,
265 Westford St., Lowell, Mass.

Brackett, Dexter, June 8, 1874.
Assistant Engineer, City Engineer's Office, Boston,
City Hall, Boston, Mass.

Bradford, Laurence, June 8, 1874.
Civil Engineer,
Duxbury, Mass.

Bradley, William H., June 8, 1874.
Civil Engineer,
53 Devonshire St., Boston, Mass.

Bray, Charles D., December 17, 1879.
Professor of Civil and Mechanical Engineering, Tufts College,
College Hill, Mass.

Brooks, Edward H., December 16, 1885.
Civil Engineer,
76 Inman St., Cambridgeport, Mass.

Brooks, Frederick, June 8, 1874.
Civil Engineer,
31 Milk St., Room 18, Boston, Mass.

Brown, Elbridge L., May 20, 1885.
City Engineer, Brockton,
Brockton, Mass.

Burton, Alfred E., November 15, 1882.
Assistant Professor of Topographical Engineering, Massachusetts
Institute of Technology,
Boston, Mass.

Cabot, Lincoln, June 8, 1874.
Civil Engineer,
19 Congress St., Boston, Mass.

Carr, Joseph R., June 8, 1874.
Civil Engineer,
270 Broadway, Chelsea, Mass.

Carson, Howard A., June 8, 1874.
Civil Engineer,
68 Devonshire St., Boston, Mass.

Carter, Henry H., April 16, 1884.
Assistant Engineer in charge of Farm Pond Conduit,
Boston Water Works,
South Framingham, Mass.

Carven, Christopher J., October 21, 1886.
Assistant Deacon Waste Water Detector,
Boston Water Works,
1604 Dorchester Ave., Dorchester, Mass.

Chaplin, Winfield S., December 16, 1885.
Professor of Engineering in Harvard University and Dean of
Lawrence Scientific School,
16 Prescott St., Cambridge, Mass.

Cheney, John E., April 28, 1875.
Assistant City Engineer, Boston,
City Hall, Boston, Mass.

Clarke, Eliot C., April 17, 1878.
15 Brimmer St., Boston, Mass.

Coffin, Freeman S., April 21, 1886.
With M. M. Tidd, Civil and Hydraulic Engineer,
10 Tremont St. Boston, Mass.

Coffin, Walter S., March 17, 1886.
Draughtsman, Boston Main Drainage Works,
74 Tremont St., Boston, Mass.

Coggeshall, Robert C., P., June 17, 1885.
Superintendent Water Works, New Bedford,
City Hall, New Bedford, Mass.

Cook, Mayo T., June 17, 1885.
City Engineer's Office,
Boston, Mass.

Corthell, Elmer L., January 20, 1886.
Chief Engineer, Atlantic and Pacific Ship Railway,
34 Nassau St., New York, N. Y.

Crafts, George H., September 17, 1884.
Civil Engineer and Contractor for Iron Bridges.
44 Fitien Building, Atlanta, Ga.

Currier, George C., March 17, 1886.
City Engineer's Office,
City Hall, Boston, Mass.

Curtis, Joseph H., December 2, 1874.
Landscape Engineer and Gardener,
85 Devonshire street, Boston, Mass.

Danforth, J. H., June 15, 1881.
With New Jersey Steel and Iron Co.,
Trenton, N. J.

Davis, Edmund S., December 18, 1878.
Examiner, U. S. Surveyor General's Office,
Denver, Col.

Davis Joseph P., June 8, 1874.
1 East Ninth street, New York, N. Y.

Davis, Thomas W., April 16, 1879.
City Surveyor, Boston.
City Hall, Boston, Mass.

Doane, Thomas, June 8, 1874.
Civil Engineer,
21 City Sq., Charlestown, Mass.

Drake, Albert B., May 19, 1886.
City Surveyor, New Bedford,
City Hall, New Bedford, Mass.

Eaton, Horace L., March 19, 1879.
Civil Engineer, City Engineer's Department, Boston,
City Hall, Boston, Mass.

Edmond, Sumner R., May 20, 1885.
Ass't Division Road Master, Boston & Worcester Division,
Boston & Albany, Railroad.
B. & A. R.R. Station, Boston, Mass.

Ellis, S. Clarence, April 17, 1878.
City Hall, Boston, Mass.

Ellis, George A., May 19, 1886.
Engineer and Superintendent of Construction, Racine Water Works,
Racine, Wisconsin.

Ellis, John W., May 19, 1886.
Chief Engineer, Providence & Worcester Railroad,
Woonsocket, R. I.

Evans, George E., April 21, 1886.
City Engineer, Lowell,
City Hall, Lowell, Mass.

Felton, Samuel M., Jr., May 17, 1882.
First Vice-President, New York, Lake Erie & Western Railroad Company,
21 Cortlandt St., New York, N. Y.

Fisher, Francis D., November 17, 1875.
Civil Engineer,
6 Clinton Pl., Syracuse, N. Y.

FitzGerald, Desmond, June 8, 1874.
Superintendent Western Division, Boston Water Works,
Brookline, Mass.

Folsom, Charles W., May 16, 1877.
Civil Engineer,
19 Berkeley St., Cambridge, Mass.

Forbes, Arthur W., April 17, 1878.
Hydraulic and Civil Engineer,
101 Milk St., Boston, Mass.

Forbes, F. F., May 21, 1879.
Superintendent Brookline Water Works,
Brookline, Mass.

Francis, James, September 16, 1885.
Agent and Engineer,
Proprietors of the Locks and Canals on Merrimack River,
Lowell, Mass.

Francis, James B., July 3, 1848.
Consulting Engineer,
Proprietors of the Locks and Canals on Merrimack River,
Lowell, Mass.

Freeman, John R., January 19, 1881.
Civil and Hydraulic Engineer,
Care of Boston Manufacturers Mutual Fire Insurance Company,
31 Milk St., Boston, Mass.

French, Alexis H., June 8, 1874.
Civil Engineer and Surveyor,
Cypress St., Brookline, Mass.

Fteley, Alphonse, June 8, 1874.
Executive Engineer New York Aqueduct Commission,
215 Stewart Building, New York, N. Y.

Fuller, Frank L., June 8, 1874.
Civil Engineer,
Engineer, Ware, (Mass.) Water Works,
7 Exchange Pl., Boston, Mass.

Glover, Albert S., June 17, 1885.
Water Registrar and Clerk of Water Board of City of Newton,
City Hall, West Newton, Mass.

Gould, John A., Jr., October 21, 1886.
Civil Engineer, City Engineer's Department, Boston,
City Hall, Boston, Mass.

Gowing, Earle H., November 19, 1884.
Mechanical Engineer, with Worthington Pump Company,
70 Kilby St., Boston, Mass.

Granger, W. P., November 15, 1882.
Chief Engineer Oregon Southern Improvement Co.,
Empire City, Oregon.

Grant, M. G., March 24, 1875.
Civil Engineer,
97 Mt. Vernon St., East Somerville, Mass.

Gushee, Edward G., December 19, 1877.
Civil Engineer, with C. Shaler Smith, Bridge Entrance, St. Louis.
4,027 Morgan St., St. Louis, Mo.

Haagensen, Sophus, December 16, 1885.
Civil Engineer. Specialty, Sub Marine Work.
33 Rialto Building, corner of Milk and Devonshire Sts.
Boston, Mass.

Haberstroh, Charles E., September 16, 1885.
Assistant Superintendent Western Division Boston Water Works.
South Framingham, Mass.

Hale, Richard A., March 15, 1882.
Principal Assistant Engineer Essex Water Power Co.,
Lawrence, Mass.

Hall, Willis H., March 17, 1886.
Engineer and Draughtsman with E. D. Leavitt, Jr.
P. O. Box 47, Cambirdgeport, Mass.

Hammatt, Edward A. W., February 18, 1885.
Civil and Hydraulic Engineer,
5 Pemberton Sq., Boston, Mass.

Hardy, George R., June 8, 1874.
Assistant Chief Engineer, Road Department, B. & A. R. R.,
Boston, Mass.

Harrington, Ephraim, February 21, 1883.
Civil Engineer,
Chief Engineer's Office, Tol., Cin. & St. Louis R. R.
Toledo, Ohio.

Harris, Charles, April 17, 1878.
Agent of Barber Asphalt Paving Co., of Washington, D. C.
101 Milk St., Boston, Mass.

Hart, Frank S., May 19, 1886.
Assistant Engineer, Proprietors of the Locks and Canals on
Merrimack River, Lowell.
Lowell, Mass.

Haskell, John C., April 18, 1877.
City Engineer, Lynn,
City Hall, Lynn, Mass.

Herschel, Clemens, June 8, 1874.
Hydraulic Engineer, Holyoke Water Power Co.,
Holyoke, Mass.

Hodgdon, Frank W., April 19, 1882.
Assistant Engineer, Massachusetts Harbor and Land Commission,
Commonwealth Building, 65 Bowdoin St. Boston, Mass.

Holbrook, F. W. D., October 2, 1874.
Superintendent Yellowstone Division, N. P. R. R.
Glendive, Montana.

Howe, Edward W., June 8, 1874.
Assistant Engineer, City Engineer's Office, Boston,
City Hall, Boston, Mass.,

Howland, Albert H., June 8, 1874.
Civil Engineer,
12 West St., Room 20, Boston, Mass.

Howland, Arthur H., January 21, 1885.
Civil and Hydraulic Engineer,
United States Hotel, Boston, Mass.

Hunking, Arthur W., May 20, 1885.
Civil and Hydraulic Engineer,
Proprietors of the Locks and Canals on Merrimack River.
Lowell, Mass.

Jackson, William, June 8, 1874.
City Engineer, Boston,
City Hall, Boston, Mass.

Jameson, Charles D., May 19, 1886.
Instructor in Civil Engineering, Massachusetts Institute of
Technology,
Boston, Mass.

Johnson, James W., May 21, 1884.
Civil Engineer,
Riverside, California.

Johnson, Daniel H., January 21, 1880.
Hydraulic Engineer,
86 and 88 Liberty St., New York, N. Y.

Jones, J. Edwin, November 19, 1879.
Civil Engineer and Surveyor,
Jamaica Plain, Mass.

Keith, Herbert C., January 20, 1886.
Assistant Engineer N. Y. & N. E. R.R.,
224 Federal St., Boston, Mass.

Kettell, Charles W., June 8, 1874.
Draughtsman, with George F. Blake Manufacturing Co., Boston,
39 Chestnut St., Charlestown, Mass.

Kidd, Alexander L., January 21, 1885.
First Assistant Engineer, Sewer Department, Boston,
City Hall, Boston, Mass.

Kimball, George A., April 28, 1875.
City Engineer, Somerville,
City Hall, Somerville, Mass.

Knapp, Frederick B., April 21, 1886.
Superintendent of Buildings and Instructor in Engineering Department, Harvard University, 14 Sumner St.,
Cambridge, Mass.

Lanza, Gaetano, February 15, 1882.
Professor of Theoretical and Applied Mechanics,
Mass. Institute of Technology,
Boston, Mass.

Learned, Wilbur F., June 8, 1874.
Assistant Engineer, Boston Water Works,
Watertown, Mass.

Leavitt, E. D., Jr., January 21, 1880.
Mechanical and Consulting Engineer,
604 Main St., Cambridgeport, Mass.

Libbey, Forrest L., November 18, 1885.
City Engineer's Office,
Boston, Mass.

Locke, Augustus W., October 18, 1882.
Manager Troy & Greenfield R. R. and Hoosac Tunnel,
North Adams, Mass.

Manley, Henry, June 8, 1874.
Assistant Engineer, City Engineer's Office, Boston,
City Hall, Boston, Mass.

Marble, Arthur D., December 19, 1883.
Acting City Engineer, Lawrence,
City Hall, Lawrence, Mass.

Mason, James D., March 24, 1875.
Assistant Engineer, Topeka, Salina & Western R. R.,
Cor. 6th and Tyler Sts., Topeka, Kan.

McClintock, William E., December 15, 1880.
City Engineer, Chelsea,
City Hall, Chelsea, Mass.

Miner, Franklin M., April 20, 1881.
Surveyor's Office, City Hall, Boston, Mass,

Minot, Samuel L., March 17, 1886.
7 Exchange Pl., Boston, Mass.

Mitchell, Henry, June 8, 1874.
Coast and Geodetic Survey and Mississippi River Commission,
Coast Survey Office, Washington, D. C.

Mudge, Benjamin C., May 19, 1886.
New England Sales Agent for Henry R. Worthington Pump Co.,
Room 3, 70 Kilby St., Boston, Mass.

Nelson, George A., April 21, 1886.
Assistant in City Engineer's Office, Lowell,
City Hall, Lowell, Mass.

Nichols, William Ripley, May 15, 1878.
Professor of General Chemistry, Mass. Institute of Technology,
Mass. Institute of Technology, Boston, Mass.

Nott, Samuel, July 3, 1848.
Civil Engineer,
212 High St., Hartford, Conn.

Noyes, Albert F., June 18, 1879.
City Engineer, Newton,
City Hall, West Newton, Mass.

Oliver, M. W., June 8, 1874.
Civil and Mechanical Engineer,
1 Bradford St., Lawrence, Mass.

Palfrey, Hersey G., December 16, 1885.
Insurance Agent,
Care of W. S. Goodell & Son, Haverhill, Mass.

Parker, Charles H., December 16, 1885.
Mechanical Engineer, Charles River Iron Works, Cambridgeport,
302 Harvard St., Cambridgeport, Mass.

Parsons, Charles S., April 21, 1880.
Chief Clerk, City Engineer's Department, Boston,
City Hall, Boston, Mass.

Perkins, Seth, April 16, 1884.
Assistant Engineer, Boston Park Department and Boston Water Works,
74 Tremont St., Boston, Mass.

Philbrick, Edward S., June 8, 1874.
Consulting Engineer,
12 West St., Boston, Mass.

Phillips, Henry A., November 19, 1884.
Division Supt., Boston, Barre & Gardner Div., Fitchburg R.R.,
Worcester, Mass.

Phinney, H. W. B., October 15, 1879.
Resident Engineer, Suburban Rapid Transit R.R.,
622 East 141st St., New York, N. Y.

Pierce, William T., November 18, 1885.
Assistant Engineer, office of E. W. Bowditch, 60 Devonshire St., Boston,
Watertown, Mass.

Porter, Dwight, November 18, 1885.
Instructor in Civil Engineering, Mass. Institute of Technology,
Boston, Mass.

Putnam, Charles E., March 18, 1885.
Transitman, Boston Main Drainage Works,
74 Tremont St., Boston, Mass.

Quimby, Ralph A., February 18, 1885.
Draughtsman, Sewer Department, Boston,
City Hall, Boston, Mass.

Rice, George S., June 8, 1874.
Superintendent Pelican and Dives Mining Co.,
Georgetown, Col.

Rice, L. Frederick, June 8, 1874.
Architect and Civil Engineer,
4 Pemberton Sq., Boston, Mass.

Sampson, George T., March 20, 1878.
Principal Assistant Engineer N. Y. & N. E. R.R.,
224 Federal St., Boston, Mass.

Saville, George G., September 21, 1881.
With the Eames Vacuum Brake Co.,
123 Oliver St., Boston, Mass.

Sawyer, Edward, June 8, 1874.
Civil Engineer,
60 Congress St., Boston, Mass.

Sewall, James W., December 17, 1884.
Firm of J. W. & T. Sewall, Civil Engineers,
Old Town, Maine.

Shaw, Edward S., February 16, 1881.
Bridge and Consulting Engineer,
5 Pemberton Sq., Boston, Mass.

Shepard, Walter, June 8, 1874.
Assistant Engineer B. & A. R.R., Boston.
Arion St., Dorchester, Mass.

Sherburne, Fred. B., March 17, 1886.
City Engineer's Office,
Boston, Mass.

Shirreffs, Reuben, December 18, 1878.
Stewart, Shirreffs & Co., Civil and Contracting Engineers,
Richmond, Va.

Smilie, Edward S., April 18, 1883.
Civil Engineer and Surveyor,
Newton, Mass.

Smith, Melvin B., May 19, 1886.
Civil Engineer and Surveyor,
26 Hildreth Building, Lowell, Mass.

Smith, Sidney, June 17, 1885.
Assistant Engineer, Boston Water Water Works,
36 White St., East Boston, Mass.

Spalding, Frederic P., June 17, 1885.
City Engineer's Office,
51 City Hall, Boston, Mass.

Stearns, Frederic P., November 15, 1882.
Executive Engineer, Boston Main Drainage Works,
74 Tremont St., Room 11, Boston, Mass.

Stearns, W. H., January 20, 1886.
Assistant Road Master, Division No. 2. B. & A. R. R.,
West Brookfield, Mass.

Story, Isaac M., February 15, 1882.
With Keene Granite Co.,
19 Exchange Pl., Boston, Mass.

Swain, George F., January 18, 1882.
Assistant Professor of Civil Engineering,
Mass. Institute of Technology,
Boston, Mass.

Swan, Charles H., May 17, 1882.
Hydraulic and Sanitary Engineer,
25 Wabon St., Roxbury, Mass.

Tidd, Marshall M., October 15, 1884.
Civil and Hydraulic Engineer,
10 Tremont St., Boston, Mass.

Tinkham, S. Everett, September 15, 1878.
Civil Engineer,
City Hall, Boston, Mass.

Tilden, James A., March 17, 1886.
Engineer and Designer with Hersey Brothers, South Boston.,
Care of Hersey Brothers, South Boston, Mass.

Tompson, George M., May 19, 1886.
Chief Engineer Boston & Lowell Railroad,
Room 13, Boston & Lowell Depot, Boston, Mass.

Tucker, Frank C., June 18, 1874.
Resident Engineer Burlington & Missouri River R. R.
Broken Bow, Custer Co., Nebraska.

Turner, E. K., June 18, 1874.
Chief Engineer Fitchburg R. R.
Fitchburg, Mass.

Vose, George L., November 16, 1881.
Brookline, Mass.

Wales, Frederick N., December 19, 1883.
Draughtsman and Assistant Engineer,
Massachusetts Board of Harbor and Land Commissioners,
Commonwealth Building, 65 Bowdoin St., Boston, Mass.

Walling, H. F., May 21, 1884.
Topographer, United States Geological Survey,
2 Pemberton Sq., Room 19, Boston, Mass.

Watson, William, January 17, 1877.
Secretary of the American Academy of Arts and Sciences.
107 Marlborough St., Boston, Mass.

Whitaker, Channing, October 20, 1875.
Consulting Engineer, Specialties, Mill and Steam Engineering,
24 and 25 Post Office Building, Lowell, Mass.

Whitney, Frank O., January 15, 1879.
City Hall, Boston, Mass.

Whittaker, William, October 18, 1876.
Contractor,
163 Cambridge St., Worcester, Mass.

Wight, W. Wendell, April 15, 1885.
Civil Engineer,
Natick, Mass.

Wilkes, C. M., March 19, 1884.
Civil Engineer,
5 Bulfinch Pl., Boston, Mass.

Winslow, Frederic I., June 17, 1885.
City Engineer's Office,
City Hall, Boston, Mass.

Wood, Henry G., June 8, 1874.
Shoe Manufacturer, Firm of J. O. Wilson & Co.,
Natick, Mass.

Woods, Henry D., April 15, 1885.
Civil Engineer,
69 Mt. Vernon St., Boston, Mass.

Woodward, R. E., January 15, 1879.
Civil Engineer,
17 Mossland St., Somerville, Mass.

Worcester, John, June 17, 1885.
Civil Engineer,
Waltham, Mass.

Young, Thomas J., March 21, 1883.
Superintendent of Sewers, Boston,
City Hall, Boston, Mass.

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